THE ENGINEER

SEPTEMBER 12, 1952

Progress at Coryton Refinery

WE were recently invited by the Vacuum Oil Company, Ltd., to visit the site of its new refinery which is under construction at Coryton, on the north bank of the Thames in Essex. Construction is making good progress at the refinery, and the main units are now beginning to take shape, after the completion of extensive preliminary civil engineering works. A description of the refinery was given in our issue of May 2nd last, page 605, to which the reader should refer for fuller details, including the flow diagram of the refinery; but some brief notes are included here of some of the points of particular interest. It may be recalled that the refinery will have a capacity approaching a million tons annually, and is expected to be completed next year, its cost being of the order of £12 million. The products will include petrol, diesel oil and basic stocks for blending to form lubricating oils. The refining installations include a "Thermofer" catalytic cracking unit; this unit is claimed to give a higher yield of petroleum products for a smaller capital outlay than catalytic cracking plants of other sorts. The catalyst consists of pellets, which flow by gravity through the cracking chamber, and then through the regenerator, where carbon is burnt off the spent catalyst. The regenerated catalyst is then blown by compressed air to the top of the unit, which is 272ft in height, and the cycle is repeated. At present the reinforced concrete substructures of this unit has been erected, and the erection of the steelwork of the tower is just starting. Another unit of particular interest at Coryton is the percolation unit, which employs a continuous process and is the first of its kind, apart from a pilot plant in the U.S.A., to be built so far. Storage of crude oil in the tanks of the refinery has already been started. The first major unit to be completed will be the power-house, which contains three boilers, each supplying steam to a 5MW turbo-alternator set; the fuel burnt in the boilers will be propane-tar, a by-product which can be conveniently used for that purpose.

Dry Docks Construction

THE Institution of Civil Engineers has published a memorandum which it describes as "a collection and correlation of the many aspects of the problems which require to be solved before the design and construction of a new dry dock can be undertaken." It has been prepared by a special committee of the Institution, on which the Institution of Mechanical Engineers, the Institution of Electrical Engineers, the Institution of Naval Architects, the Admiralty, and the United Kingdom Chamber of Shipping were represented. The memorandum is divided into five main sections dealing with classification, dimensions and siting; dock structure; caissons and gates; mechanical and electrical equipment; and miscellaneous equipment. The first section mentions a system of classification of dry docks by size and suggests a uniform system for quoting dimensions of any docks. Considerations governing siting and site investigations are also discussed. The section on dock structure deals with what may be described as the main civil engineering problems, e.g. the floor, walls, the entrance and the arrangements to be made therein for the various other equipment and services, such as pumps, gates, cranes, &c. The third section covers the various kinds of caissons and gates. The section on mechanical and electrical equipment deals fully with the various types of main pumps and the functions of the various auxiliary pumps to be found in a modern installation, and their methods of control. Cranes, capstans and operating machinery for gates and caissons are also discussed. The miscellaneous equipment dealt with in the final section includes keel and bilge blocks of various kinds and such equipment as docking towers, centering devices, bollards and fairleads. The memorandum is not illustrated, but has a list of references and an index; copies are available on application to the Secretary, Institution of Civil Engineers, price 7s. 6d. paper covered, 10s. 6d. cloth bound.

The British Waterworks Association

ON Wednesday last, September 10th, the forty-first annual general meeting and conference of the British Waterworks Association started in Edinburgh. The programme of events included the presidential address and the presentation for discussion of two papers on Wednesday, with visits to works on Thursday, to-day and to-morrow. The Association's annual dinner will take place to-morrow night. The new president of the Association is Provost Andrew Wallace. During the course of his address, Mr. Wallace noted that the demand for water for domestic needs was by no means yet satisfied. Sample figures which had been collected, he said, appeared to show that, of 14½ million households in Great Britain, 95·5 per cent had a piped water supply, but 5½ million had no fixed bath. In rural areas 80 per cent of households had a piped supply, he continued, the Eastern Counties being least well off with nearly 40 per cent of rural households without a supply. Mr. Wallace remarked that in the past year the Association had had to meet current and, he hoped, temporary, difficulties, but the problem of the extension and improvement of water supplies had not been lost sight of. Of the two papers presented at the meeting, one is devoted to the works of the Stirlingshire and Falkirk Water Board, and is reproduced in abstract elsewhere in this issue; it contains a description of a filtration plant which is automatically controlled, and is thought to be the first large plant of this kind owned by a local water authority. The second paper is entitled "Some Notes on the Organisation, Practice and Works of the Edinburgh Corporation Water Undertaking," by G. Baxter, the city water engineer. Mr. Baxter's paper includes interesting notes on the detection of waste, and on tests to determine the water requirements of a modern dairy farm; tests were also carried out to establish what effect a communal hot water supply had upon consumption, confirming that the amount of water per head is, for all practical purposes, doubled when such a supply is available. The new works of the undertaking include the construction of a tunnel, 1½ miles long, connecting two intake weirs with the Talla reservoir, and details of the cycle of tunnelling operations and of the costs of tunnelling are given in the paper. A distribution scheme, including a filtration works with an initial output of 3 m.g.d. is also being built to meet the requirements of the development of the Lothian coalfield; the filtration plant consists of two micro-strainers of 7ft 6in diameter and five slow sand filters. Lastly, a service reservoir of 4 m.g. capacity is being built at Firrhill.

Europe's Coal Problems

THE coal committee of the United Nations Economic Commission for Europe last week concluded a meeting in Geneva, at which delegates from sixteen countries were represented. In the course of its deliberations, the committee considered a report dealing with measures recommended for the efficient use of solid fuels. This report suggested that it would be advantageous if, in countries where they do not already exist, fuel advisory services could be set up as soon as possible. It would also be an advantage the report continued, if in countries where fuel advisory services were in existence steps could be taken to ensure that they were in a position to perform their tasks effectively. The report referred to the desirability of setting up "thermal centres," the function of which might be to help industrialists by their advice to improve their fuel burning installations and use them efficiently, and to give guidance in the choice of the right kind of equipment. Another section of this report emphasised the need to increase the number of thermal technicians and to develop, by every possible means, technical training in the efficient use of fuel.

The Colonial Civil Aviation Conference, 1952

ON Monday last, the second Colonial Civil Aviation Conference was opened at the Colonial Office, Sanctuary Buildings, Great Smith Street, S.W.1, by the Earl of Munster, Parliamentary Under-Secretary of State for the Colonies. The purpose of the conference, at which about forty Colonial territories are being represented, is to review the progress of civil aviation made in these territories and in particular to discuss the influence which the gas turbine propelled craft will have upon them. Representatives of the Ministry of Civil Aviation, the Ministry of Supply, and the Air Ministry are also attending the conference. Consideration will be given also to the effects on the Colonies of the change in United Kingdom civil aviation policy as announced in the House of Commons on May 27th. The proceedings of the conference, which are private, commenced with a public session, in which the Earl of Munster, referred to the recent tremendous progress which was apparent in the new aircraft at the S.B.A.C. display.

Ash and Clinker in Industry

THIS week the Institute of Fuel has issued some further details about the conference which it is arranging on the subject of ash and clinker in industry. The conference is to be held on Tuesday and Wednesday, October 28th and 29th, in the hall of the Institution of Mechanical Engineers, Storey's Gate, Westminster, S.W.1. The object is to discuss, in its broadest sense, the effect of ash and clinker upon industrial processes, with special reference to steam raising. As has been pointed out by Dr. A. C. Dunningham, chairman of the organising committee of the conference, ash has always adversely affected combustion processes using solid mineral fuels. But it has caused new difficulties as industrial techniques have been extended in the direction of larger boiler units and higher temperatures and pressures. Moreover, there is a tendency towards the production and marketing of coals having a higher ash content than formerly. The papers to be presented for discussion at the conference include consideration of the occurrence and fundamental properties of ash, methods of sampling and analysis, and the partial removal of ash from coal by cleaning processes. Problems of more practical interest to the industrialist, which are to be discussed, include the treatment and disposal of ash and clinker, the problems of deposits and corrosion and the influence of ash upon boiler design. The quantitative effect of ash upon boiler efficiency will also be considered, and it is hoped to have an authoritative account of recent work carried out by the British Coal Utilisation Research Association in this field. In addition, available methods of evaluating coals of varying ash content will be discussed in relation to the new price structure of the National Coal Board. Full particulars of the conference can be obtained from the Institute of Fuel, 18, Devonshire Street, London, W.1.

High - Altitude Research

By E. BURGESS, F.R.A.S.

No. 1

Until recent years the exploration of the physical conditions of the upper atmosphere was restricted to the use of sounding balloons, the observations of meteor trails and the aurora and the reflections of radio waves from the ionised layers. Now the modifications and developments of long-range military rockets have enabled instruments to be carried to atmospheric levels far higher than ever before. The modified "V-2s" ascend, for example, to nearly 120 miles, while newer rockets such as the "Viking" have reached 135 miles. A composite German "V-2" and American "WAC Corporal," acting as a two-step, has even attained a height of 250 miles.

FROM spring, 1946, captured "V–2" rockets were instrumented for upper atmosphere study by various research agencies and universities in the United States. This instrumentation was aimed at obtaining data on temperature and pressure, composition, ion density, cosmic ray intensity, solar spectroscopy into the extreme ultra-violet, ozone distribution, earth's magnetic field, high-altitude photography, effects of cosmic rays and free fall on seeds, fruit flies and small animals.

Acceleration of the "V–2" ranged from 1·64 "g" effective at take-off to about 6 "g's" at all-burnt, in a period of about sixty seconds. Instrument design was not, therefore, seriously hindered by excessive inertial forces. The same applied with the "Viking" rocket, but in the case of the "Aerobee" care had to be taken because of the booster stage which gave a sharp take-off acceleration of 14 "g." Weight was not

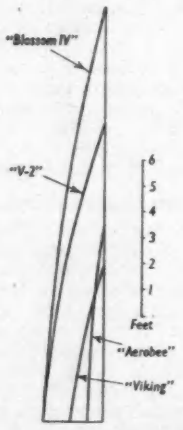


Fig. 1—Half Nose Cones of High-Altitude Rockets

of importance in the "V–2" for that rocket had been designed to carry a payload of relatively dense material, the high explosive warhead weighing 1 ton. However, space was a limiting factor because physical instruments have not a great overall density. Early rockets had to use lead ballast to keep the centre of gravity well forward of the centre of pressure to ensure aerodynamic stability. Later an attempt was made to redesign the "warhead," to increase its length by a whole calibre and thus improve the available space from 16·5 cubic feet to 80 cubic feet. The placing of heavy power supplies well forward preserved the aerodynamic stability.

The "Aerobee" is a much smaller rocket and more easily constructed and fired. Two men can, for example, carry the empty rocket. Its small payload of 150 lb occupied about half of the available space in the missile, and the relative low cost of the "Aerobee" meant that it was economical to instrument only a few experiments for each shot.

In the case of the "Viking" the payload could be adjusted over quite a large range, from 100 lb to 2000 lb, without disturbing the stability (Figs. 1 and 2).

The initial problem, of course, was that connected with the recovery of data and two methods are possible. The first is the physical recovery of the records from the wreckage after impact and the other is to telemeter instrument readings back to the ground station during flight. These two methods are obviously needed for different types of experiment and sometimes the data are recovered by both methods as a check; for example, in one case at White Sands, the cosmic ray counts were both telemetered and recorded on photographic film.

Some data cannot be telemetered, such as photographs of the earth and spectra, and some method had to be found at an early stage for the safe recovery of such films. Normally, the fins on the "V–2" bring it into a nose-down attitude as it re-enters the dense atmosphere. Without losing much speed it plunges down and digs a crater some 50ft deep. By breaking up the missile as it enters the atmosphere, the parts can be made to have poor aerodynamic properties which reduces their velocities of impact. This result is accomplished either by blowing off the warhead (in the "V–2") or the tail-skirt (in the "Aerobee"). The two parts then tumble to earth and are usually recovered in a fairly good condition. One spectrograph has, for example, been flown several times.

Some experiments, known as "Project Blossom," have been made to recover parts of the rockets by means of a high-speed parachute. Early tests were made by ejecting an instrument compartment from the "V–2" and later attempts were made to bring down the complete warhead in this manner. Small animals, such as mice and monkeys have been landed safely by this method from an altitude of 80 miles.

But most of the measurements made in upper atmosphere research can be telemetered to the ground station during the experiment. The sequence of operation is divided into three main stages:

(*a*) Measuring and transmitting.
(*b*) Receiving.
(*c*) Decoding and recording.

The first telemetering equipment was made hurriedly from equipment available at that time in 1946 when the upper atmosphere programme commenced. This was necessary because it was known that the "V–2s" would deteriorate with storage and should be used as quickly as possible. Even so, this telemetering system worked very well, although there was a tendency to experience interference due to cross-talk.

Essentially, the measuring and transmitting consisted of converting the instrument readings to voltages and periodically sampling them for transmission on a multi-channel pulse modulated system. This airborne unit is shown in schematic form in Fig. 3. A master keyer in the form of a freely running multivibrator with constant period, generates the first trigger pulse for each period of data sampling. Then the vibrator for each channel triggers the next one until the complete sequence of twenty-three channels has been sampled. The recovery time for any one multivibrator is controlled by the data voltage being sampled so that the time interval between the pulses is the measure of the instrument readings. When all the channels have been transmitted, the circuit remains quiescent until the master keyer

Fig. 2—Putting the Instrumented Nose Cone on to a "Viking" Rocket

initiates the sequence once again. The original sets had a peak r.f. power of 700W at 1000 Mc/s, but these were later improved to give 1000W output.

Calibration of the equipment is important, as constants are likely to change during the flight. It was usual to arrange to break the connection periodically between the data voltage source and the airborne modulator channels and substitute two controlled potentials, first zero, or earth potential, and then a suitable reference voltage of 3·5V. Two

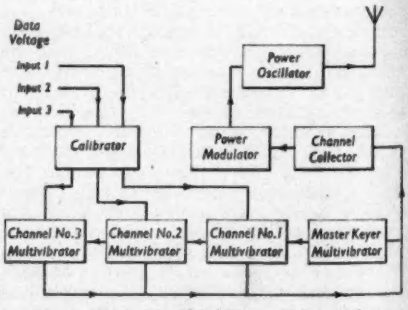


Fig. 3—Diagram of Airborne Telemetering Transmitter

of the calibrating units would be mounted in each airborne transmitter. Although the complete unit for use in the rocket had to be included in a sealed pressurised container in order to prevent corona discharge and arc-over, it was a compact piece of apparatus. The airborne unit weighed 150 lb and in its

sealed case it measured only 14in by 14in by 20in.

The "Aerobee" rocket had to employ a much simpler system. This was a frequency-modulated - on - frequency - modulated six - channel, 85 Mc/s unit developed by the Applied Physics Laboratory. The transmitting aerial was at the nose tip and the complete equipment weighed 20 lb. It had an accuracy of better than ±5 per cent.

Reverting to the original system the ground station as first employed was mobile, and consisted of two complete stations mounted in towed trailers with powered generating vehicles. In addition to the 1000 Mc/s receiver, a video amplifier, and decoding unit, each trailer contained recording and test equipment and communication transmitter receivers for contacting base. There were also accurate timing devices. These two stations received, decoded and recorded the data transmitted from the rocket. Their aerials were mounted with servo-motors so that they could follow the rocket either controlled by the optical trackers or by a radio-signal maximising system. Later a complete building was constructed to contain the ground station and thus became a permanent feature of the proving grounds. Fig. 4 shows the sequence of operations which ran essentially as follows. The received signal was amplified and detected then passed through suitable amplifiers to a decoder. This apparatus recreated the original data voltages from the time-modulated signals, which were being received. These voltages were then used to operate meters for each of the channels and the bank of meters was photographed with a 35mm cine camera. In order to prevent loss of vital data should the recorder fail, several different systems of recording were used simultaneously.[1] The output from the video amplifier was recorded on magnetic tape, and also through an oscilloscope by means of a 16mm continuous film camera. The channel outputs from the decoder were also registered on a moving strip of photographic paper by means of Hathaway magnetic string oscillographs.

The decoder itself had a very similar sequence of operation to the transmitter. The incoming pulses were fed to a synchronising pulse generator, and also to the input of a channel separator via a pulse inverter. At the beginning of each group of pulses received, the synchronising pulse generator developed one single pulse which passed to the separator of channel No. 1, and triggered a multi-vibrator which did not return to its ground state until it received the second pulse of the chain arriving from the pulse inverter. The return of the first separator to its ground state triggered No. 2, which again returned to normal on the arrival of the third pulse from the transmitter. The sequence continued with each channel separator triggering the next until the complete series of channels had been passed through. During the conduction period of each separator a constant voltage would be applied to its associated metering circuit for the length of time which represented the original data voltage registered by the instruments in the rocket. By means of suitable resistance-capacity time effects a condenser was permitted to charge to a potential which depended upon the duration of the applied voltage, and hence upon the telemetered data. A valve voltmeter was used to show the original voltage.

This system has proved quite accurate and reliable. At first dipoles were used on both the rocket and the ground station, but it was then found that the signal could be lost due to cross polarisation when the rocket rolled after "all-burnt," a state of affairs which often happened, for any angular momentum given by the motor at the instant of cut-off could not be later corrected. Circularly polarised tripole aerials followed later by turnstile aerials obviated these effects.

It is of great importance that all equipment in rockets should function correctly under varying power potentials, for as the storage batteries discharge, a drop in voltage is usually experienced. For high potentials dry batteries were used, and aircraft-type unspillable accumulators were employed for the low tension. In some later rocket instrumentations, anode voltages were obtained from inverters giving 120V at 400 c/s, but for the geiger tubes and other high-tension requirements, dry batteries were still

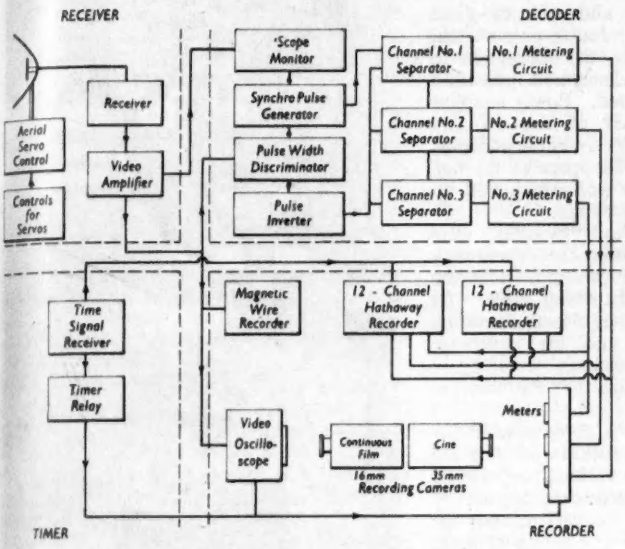


Fig. 4—Diagram of Ground Station of Telemetering System

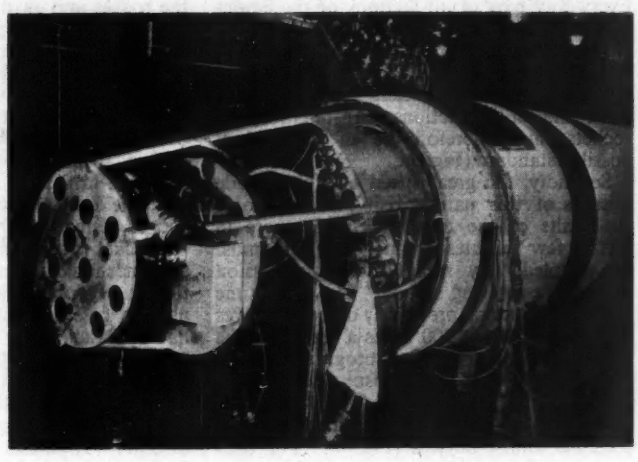


Fig. 6—Nose Section of "Viking" No. 1, Showing "NRL" Equipment and Timer

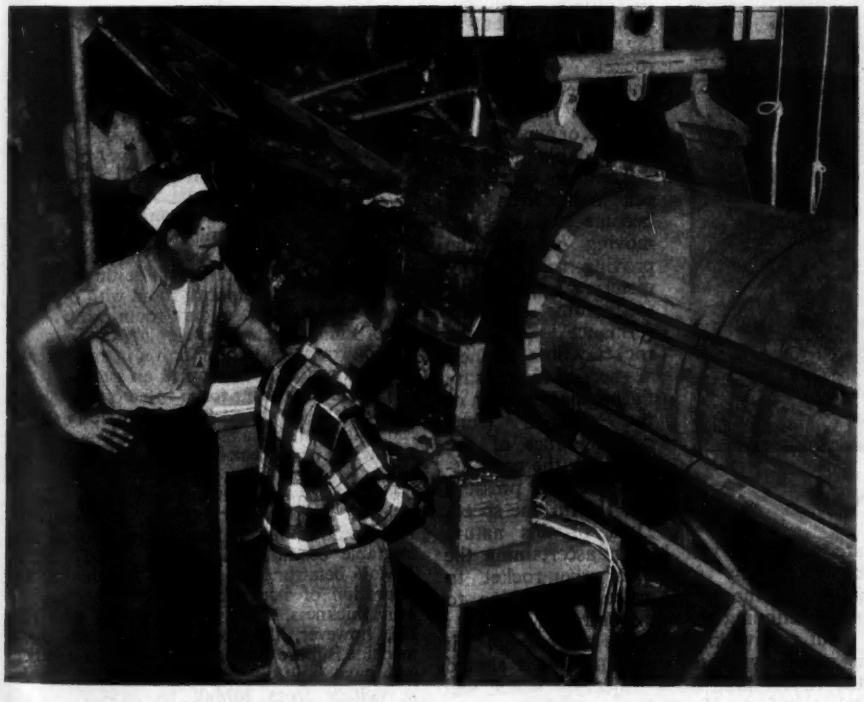


Fig. 5—Checking Power Plants of "Viking" Rocket

retained when there was low drain and close voltage regulation.

There are certain peculiarities in rocket instrumentation which are completely independent of the type of experiment to be performed. First, experiments in rockets are much different from those which are conducted in the laboratory on the ground or in a mobile test such as in an aircraft. Once the rocket has taken off no further correction or adjustment can be made to the test apparatus. Every tiny part of all sections of the equipment must function correctly when the firing button is depressed. Moreover, the failure of one section of the experiment can often invalidate or make useless data recovered from the other sections. Installations in rockets must therefore be of the highest possible standard (Fig. 5).

Secondly, the great speed of high-altitude missiles of this nature, rising as they do to the limits of the terrestrial atmosphere in just a few minutes means that data must be sampled very rapidly for transmission on the telemetering system. The pulse time modulated system, previously described, gives a sampling rate of 300 times a second. The high speed also limits photographic work because it reduces the exposures which may be given.

The rapid sampling of data necessitates accurate timing devices (Fig. 6). For telemetering, the data are correlated with radar tracking plots, optical observations and photographic methods of recording the trajectory by using a master timing device. This enables the data to be plotted as an accurate function of the altitude of the rocket throughout the flight. In the timing device a timing pulse was generated every half second on a background of a 100 c/s note. This begins at the instant of take-off and every twentieth pulse after that time was cancelled. Accurate timing was thus ensured. In addition to the electronic timer a mechanical timer was also usually included to control such operations as the starting of cine cameras, opening pressure gauges or sampling bottles, starting the transmitter for the ionosphere experiment, exposing spectra and controlling the cosmic ray cloud chamber, finally blowing off the warhead or the tail-skirt for the air break-up. This timer consisted of a 4000 r.p.m. "Oster" constant-speed d.c. motor which operated through a series of gear chains to drive a camshaft at one rotation in every 400 seconds. There were five cams mounted on the shaft and each of these operated a single-throw, double-pole switch. The poles operated both the equipment in the rocket and gave a telemetered indication that the cam had operated. Power supplies for the motor consisted of two 6V dry batteries connected in series. These occupied about half of the available space in the box which housed the timer and which had an overall size of 6in by 6in by 8in.

Two push-to-open tail switches were mounted in the tail of the rocket where they were held in the open position while the rocket rested on the launching table. As the rocket rose the switches closed, operating the mechanical timer and the electronic timer. Double-pole switches were again used to give an indication that the switches had operated.

Many different agencies co-operate in the firing of a high-altitude rocket and it is the synchronisation of these various participants which causes perhaps the greatest amount of trouble. High-altitude rockets cannot be fuelled and then left for any length of time, or else the low-temperature liquefied gases of the fuels start to give trouble by causing the icing-up of valves. Hence, when the word is given for the launching to take place (Fig. 7) the instrumentation must be completed in accordance with the firing schedule. It is essential that the many months of work in all the fields of instrumentation and design, in missile checking, servicing and fuelling, should culminate at the right time on the right date for the test. With the vagaries of climate, even in the desert, this problem becomes one of first magnitude. Indeed, someone once went as far as to say that in the rocket world one has either "just had trouble, is having trouble, or expecting to have trouble" (Fig. 8).

Fig. 7—"Viking" Ready for Firing

The rocket, too, can malfunction and become a danger by moving out of the proving area. Telemetering is thus used to monitor the performance of the rocket. Six channels are needed to measure the angular position of the controls (four carbon vanes of the "V–2"), the combustion chamber pressure and the turbine speed. Data of this nature are extremely valuable in ascertaining the cause of any failure of the rocket to ascend to the height calculated or due to malfunctioning of the control system.

But passive knowledge is not enough; it is necessary to terminate the flight should the rocket take up a trajectory which will carry it from the safe proving area. An emergency cut-off receiver is thus employed.

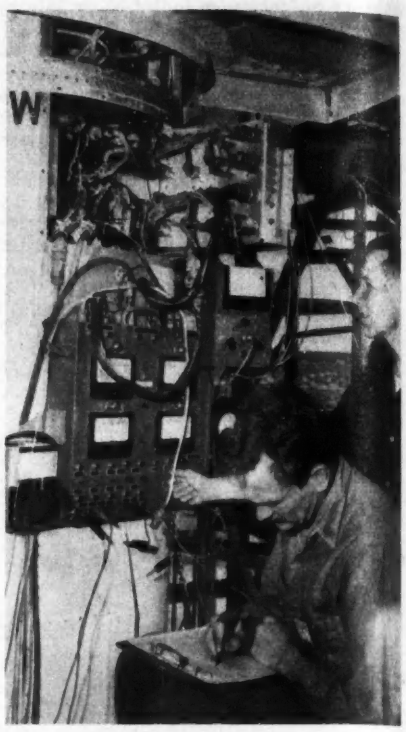


Fig. 8—Telemetering Equipment in the Nose of a "Viking"

Ordinary radio-control receivers were employed in the "V–2s," and as these frequency-modulated receivers had several channels they were also used as a safety measure to consolidate the mechanical timer instructions for such matter as triggering the air-burst. Weighing 17 lb the airborne receiver was crystal controlled at 40 Mc/s and measured 4⅝in by 9½in by 8⅝in.

(To be continued)

Installation of a 22MeV Betatron

THE Allis-Chalmers Manufacturing Company recently completed a new concrete building at its West Allis, Wisconsin, works to house a 22MeV betatron for use in inspecting large steam turbine, centrifugal pump and hydraulic turbine parts. The new building, which is 86ft long by 74ft wide, has reinforced concrete walls 6ft thick and 20ft high to shield the personnel from betatron radiation. An overhead travelling bridge crane capable of handling 25 tons, will be used for lifting the specimens. In addition to the testing area, the building also has a control room with operating panels and circuits, a dark-room with a dual set of stainless steel developing tanks, and a viewing room for the inspection of radiographs. The betatron will be mounted on a crane, which will permit the beam to be rotated through 180 deg. about the horizontal axis and 360 deg. about the vertical axis of the focal spot. The castings to be inspected will be placed below the unit.

Since 1948 the company has had a 22MeV betatron in a smaller building at West Allis. This betatron has a fixed beam instead of a rotatable beam. It has been found that the 22MeV betatron can be used for the effective inspection of steel sections from 1in to about 24in thickness. For thicknesses of less than 1in, however, the conventional 220kV X-ray machine is more efficient. By 1953, the company will have built twenty-four betatrons, ranging in voltage from 20MeV to 24MeV. These units, which have been in production since 1944, are used in industry, medicine and research.

Strain Rosette Analysis

By H. FEALDMAN, M.A. (Cantab)

This article describes methods of analysing the results obtained from the use of multi-element wire resistance strain gauges in which the separate elements are variously oriented at a point. The theory underlying the Mohr's circle representation of two dimensional stress and an analogous circle for strain is developed. Purely graphical methods for resolving the readings from two kinds of rosettes based on such circles are then explained and the analytical solutions are also included.

THE experimental measurement of strain by means of strain gauges of various types is now an everyday practice in many design offices and research laboratories. The normal use of such gauges is to determine the magnitude of the strain—and hence that of the stress—in one direction at a particular point in a stressed body. It is often necessary, however, to ascertain the stress distribution at that point as well as the magnitude. In this case there are three unknowns, which when solved, completely define the state of (two-dimensional) stress at any point. These three are the magnitude of each of the two principal stresses and the direction of one of them (the principal stresses being mutually at 90 deg. defines the direction of the other).

To solve these three unknowns three readings are necessary. These may be obtained

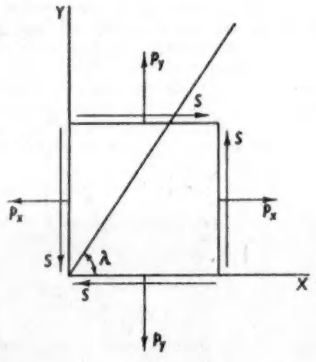


Fig. 1

from the values indicated by three strain gauges, read simultaneously, placed at the point in question with their axes inclined to one another. The physical difficulties of such an arrangement are largely overcome by the use of the small electrical wire resistance strain gauges. Other types of gauge are quite suitable, but are generally confined to large structures such as dams, heavy foundations, &c. The popularity of the electrical wire resistance strain gauge for this kind of problem has led the manufacturers of such gauges to produce standard types of multi-gauges, consisting of a number of single gauges mutually inclined to one another. Such an arrangement is known as a "strain rosette."

There are three common types of rosette in use in this country—the "90 deg. rosette"; the "Delta," or "equiangular rosette," and the "45 deg. rosette." The 90 deg. rosette consists of two single gauges at 90 deg. to each other and is used where the directions of the principal stress are obvious from physical considerations of the problem, the axes of the gauges being placed parallel to the directions of the principal stresses. The strains obtained should be substituted in equations (24) and (25) (below), which ca then be solved for the principal stresses, p_{max} and p_{min}.

The delta rosette, which is the most common, consists of three single gauges arranged mutually at 60 deg. The 45 deg. type, which is lesser used, is similar to the 90 deg. rosette described previously with the addition of a third element at 45 deg.

A rosette which is used in the U.S.A. is known as the "T Delta," and consists of four gauges, being the ordinary delta gauge with a fourth element at 90 deg. to one of the other three gauges. Many other types of rosette are possible and can be made up by the manufacturers for special purposes.

The characteristics and use of the electrical wire resistance strain gauge are now so well known that there is little point in reiterating them here. The use of strain rosettes employs precisely the same principles and methods as for single gauges. The analysis of results obtained from delta rosettes and 45 deg. rosettes are discussed below. Other types of rosettes which do not lend themselves to analysis quite so readily may be solved along similar lines, however.

Before proceeding to a consideration of the analysis of results, it is first necessary to restate and to slightly recast the basic conceptions of two-dimensional stress and strain at a point and the relationship between them.

Consideration of Two-Dimensional Stress.—The infinitesimally small element shown in Fig. 1 is acted upon by stresses as shown, where p_x and p_y are normal stresses and s the shear stress.

The normal stress p_λ and the corresponding

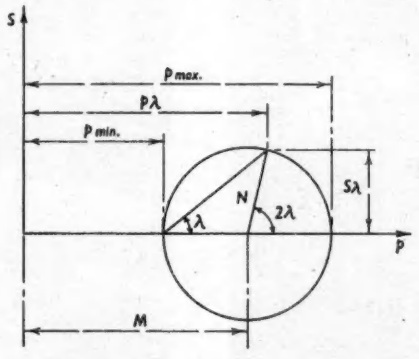


Fig. 2

shear stress s_λ on any plane inclined at an angle λ to the x axis is given by :

$$p_\lambda=\frac{p_x+p_y}{2}+\frac{p_x-p_y}{2}\cos 2\lambda+s\sin 2\lambda \quad . \quad (1)$$

$$s_\lambda=\frac{p_y-p_x}{2}\sin 2\lambda+s\cos 2\lambda. \quad . \quad . \quad (2)$$

s_λ will be zero, from equation (2), when

$$\tan 2\lambda=\frac{2s}{p_x-p_y} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

This equation defines two mutually perpendicular directions for which s_λ is zero. The normal stresses in these directions are found to be a maximum and a minimum, and are known as the principal stresses, p_{max} and p_{min}. By substitution of equation (3) in equation (1) we get,

$$p_{max}=\tfrac{1}{2}(p_x+p_y)+\tfrac{1}{2}\sqrt{(p_y-p_x)^2+4s^2} \quad . \quad . \quad (4)$$

$$p_{min}=\tfrac{1}{2}(p_x+p_y)-\tfrac{1}{2}\sqrt{(p_y-p_x)^2+4s^2} \quad . \quad . \quad (5)$$

We can now write for equations (1) and (2),

$$p_\lambda=\frac{p_{max}+p_{min}}{2}+\frac{p_{max}-p_{min}}{2}\cdot\cos 2\lambda \quad . \quad (6)$$

$$s_\lambda=\frac{p_{min}-p_{max}}{2}\cdot\sin 2\lambda \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

Let

$$M=\frac{p_{max}+p_{min}}{2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

$$=\frac{p_x+p_y}{2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

and

$$N=\frac{p_{max}-p_{min}}{2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

$$=+\tfrac{1}{2}\sqrt{(p_y-p_x)^2+4s^2} \quad . \quad . \quad . \quad . \quad . \quad (11)$$

By substitution in equations (6) and (7),

$$p_\lambda=M+N\cos 2\lambda \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

$$s_\lambda=-N\sin 2\lambda \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (13)$$

The relation between p_λ and s_λ is defined in Cartesian co-ordinates by a circle radius

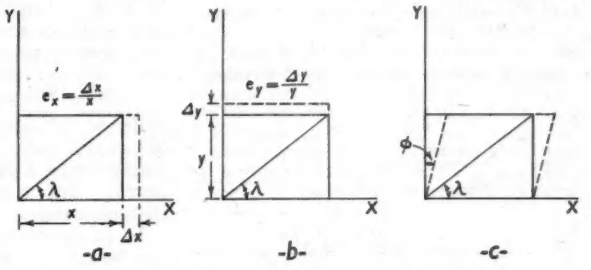


Fig. 3

N, co-ordinates of centre being (M, O) as shown in Fig. 2, and is known as Mohr's circle for stresses.

Consideration of Two-Dimensional Strain.—The infinitesimally small element shown in Figs. 3*a*, 3*b* and 3*c* is subject to the strains shown, superimposed on one another. e_x and e_y are normal strains and ϕ is the shear strain. The normal strain e_λ and the corresponding shear strain ϕ_λ on any plane inclined at an angle λ to the x axis are given by :

$$e_\lambda=\frac{e_x+e_y}{2}+\frac{e_x-e_y}{2}\cos 2\lambda+\tfrac{1}{2}\phi\sin 2\lambda \quad . \quad (14)$$

$$\phi_\lambda=(e_y-e_x)\sin 2\lambda+\phi\cos 2\lambda \quad . \quad . \quad . \quad . \quad (15)$$

By similar reasoning to that used for equations (4) and (5), the principal strains can be arrived at :

$$e_{max}=\tfrac{1}{2}(e_x+e_y)+\tfrac{1}{2}\sqrt{(e_x-e_y)^2+\phi^2} \quad . \quad . \quad (16)$$

$$e_{min}=\tfrac{1}{2}(e_x+e_y)-\tfrac{1}{2}\sqrt{(e_x-e_y)^2+\phi^2} \quad . \quad . \quad (17)$$

Similarly, let

$$M_1=\frac{e_{max}+e_{min}}{2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (18)$$

$$=\frac{e_x+e_y}{2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (19)$$

and

$$N_1=\frac{e_{max}-e_{min}}{2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (20)$$

$$=+\tfrac{1}{2}\sqrt{(e_x-e_y)^2+\phi^2} \quad . \quad . \quad . \quad . \quad . \quad (21)$$

Equations (14) and (15) can now be written :

$$e_\lambda=M_1+N_1\cos 2\lambda \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (22)$$

$$\phi_\lambda=-2N_1\sin 2\lambda \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (23)$$

Now the relationship between e and $\frac{\phi}{2}$ is defined in Cartesian co-ordinates by a

circle radius N_1, co-ordinates of centre being (M_1, O), and is called Mohr's circle for strains (as an analogy of Mohr's circle for stresses) as shown in Fig. 4.

Relation between Stress and Strain.—This relationship is only true for homogeneous and isotropic materials. Since the engineer is assumed normally to be only concerned with such materials the ordinary theory of elastic behaviour is applicable. The principal directions of strain coincide with the principal directions of stress. By use of Hooke's Law and the Poisson effect it can be deduced that :

$$e_{max}=\frac{p_{max}}{E}-\frac{\sigma p_{min}}{E} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (24)$$

and

$$e_{min}=\frac{p_{min}}{E}-\frac{\sigma p_{max}}{E} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (25)$$

where

E=Young's Modulus of Elasticity,

and

σ=Poisson's Ratio.

By substitution in equations (8), (10), (19) and (21), the relationships are obtained :

$$M=\frac{M_1 . E}{1-\sigma} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (26)$$

$$N=\frac{N_1 . E}{1+\sigma} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (27)$$

and hence,

$$p_\lambda=E\left(\frac{M_1}{1-\sigma}+\frac{N_1}{1+\sigma}\cos 2\lambda\right) \quad . \quad . \quad . \quad . \quad (28)$$

Thus the stress at any point on a plane of any desired inclination may be determined

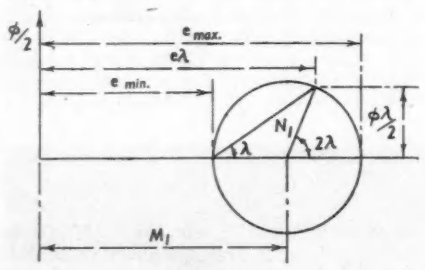


Fig. 4

from the knowledge of the components of the strain and the shear strain at that point.

Rosette Analysis.—With reference to Fig. 5, the axes of the separate elements are shown making angles with the line of the maximum principal strain, e_{max} (as yet unknown), of θ_1, θ_2 and θ_3. The elements have indicated axial strains e_1, e_2 and e_3 respectively. The angles $(\theta_1-\theta_2)$ and $(\theta_1-\theta_3)$ are dependent on the type of rosette employed and are known. By substituting, in turn, the indicated strains in equation (22), together with their respective angles (in terms of θ_1), three simultaneous equations are obtained which may be solved for M_1, N_1 and $\tan 2\theta_1$.

Delta Rosette.—The solution for the principal strains gives :

$$M_1=\frac{e_1+e_2+e_3}{3} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (29)$$

$$N_1=\frac{\sqrt{2\{(e_1-e_2)^2+(e_2-e_3)^2+(e_3-e_1)^2\}}}{3} \quad . \quad . \quad . \quad . \quad . \quad (30)$$

From equations (19) and (21),

$$e_{max}=M_1+N_1 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (31)$$

$$e_{min}=M_1-N_1 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (32)$$

To obtain the principal stresses, M and N are obtained from equations (26) and (27), and, similarly,

$$p_{max}=M+N \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (33)$$

$$p_{min}=M-N \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (34)$$

Alternatively, they may be obtained directly from the solution of equations (24) and (25).

The directions of the principal strains (and stresses) in relation to the gauge is given by :

$$\tan 2\theta_1=\frac{\sqrt{3}(e_3-e_2)}{2e_1-e_2-e_3} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (35)$$

When a large number of computations is required to be performed, the use of formulæ becomes very cumbersome and recourse has to be made to other methods. Graphical methods may be employed with great facility.

For each type of rosette many graphical methods are available, some combining analytical and graphical methods. The method described below is completely graphical and gives satisfactory results.

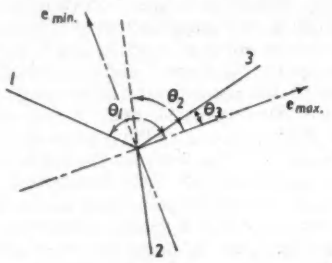


Fig. 5

With reference to Fig. 6, draw three parallel lines AB, CD and EF at distances representing e_3, e_2 and e_1 to scale respectively from a base line representing zero strain. Select an arbitrary point G on EF. Draw GH and GJ cutting CD and AB in H and J respectively, so that $E\hat{G}J=F\hat{G}H=60$ deg. The line HJ is one side of an equilateral triangle, whose vertex K lies on EF, and can now be found. The circumscribing circle of this triangle, centre L, which can now be drawn, is Mohr's circle for strain. The zero line OL can be drawn cutting the circle in P. The points K, H and J are the points representing the gauges 1, 2 and 3 respectively. $K\hat{P}L$ is the required angle θ_1 and e_{max} and e_{min} are found by direct measurement to the same scale as was adopted for e_1, e_2 and e_3. p_{max} and p_{min} can be found by solving equations (24) and (25). The proof of this construction is immediately obvious from the physical requirements of the three points on the circle.

45 *deg. Rosette.*—In this case it is assumed that elements 1 and 3 are at 90 deg. to one

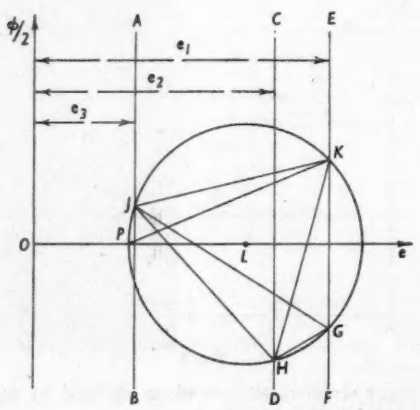


Fig. 6

another. The solution for the principal strains gives :

$$M_1=\frac{e_1+e_3}{2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (36)$$

$$N_1=\sqrt{\frac{(e_1-e_2)^2+(e_2-e_3)^2}{2}} \quad . \quad . \quad . \quad (37)$$

The principal stresses may be evaluated in a similar manner to that described for the delta gauges. The direction of the principal stresses may be determined by the equation :

$$\tan 2\theta_1=\frac{2e_2-e_1-e_3}{e_1-e_3} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (38)$$

The following graphical method is recommended for the solution of the 45 deg. rosette.

Draw two lines (Fig. 7) AB and DE parallel to the zero line OC and equidistant from it. Set off the points B and E so that AB represents e_1 to scale and DE represents e_3. Mark C so that OC represents e_2. Draw the line BE. The point F where this line cuts OC is the centre of Mohr's circle for strain. Draw BG perpendicular to OC, cutting OC (or OC produced) in G. Find H so that GH is equal to FC. (Note : if F falls to the right of C, i.e. if FC is negative, then GH should be plotted downwards.) The point H is the point representing element 1 on Mohr's circle, and consequently FH is the required radius of Mohr's circle for strains. The principal strains can now be measured directly. $G\hat{F}H$ is equal to $2\theta_1$ and consequently $G\hat{J}H$ is the required angle θ_1.

It is possible by a simple further construction to draw Mohr's circle for stresses (to a suitable scale) on the same diagram, but it is thought that it is simpler to use equations (24) and (25) or (26) and (27).

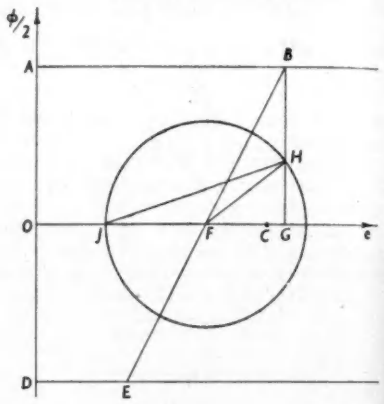


Fig. 7

The proof of this construction follows simply from equations (36) and (37). Other methods available for solution are by means of nomographs or charts, special slide rules, geometrical computers or electrical computers. In this connection computing machines normally used for other calculations may be adapted. These methods of calculation are only justified when there is a large continuous flow of problems requiring solution. All these methods are more highly developed in the U.S.A. than in this country.

It is often necessary, where electrical wire resistance strain gauges are used, to apply a correction to the individual strain readings, due to the transverse gauge sensitivity. Correction factors have been derived by the manufacturers and it is suggested that they should be contacted when ordering the rosettes, if accuracy of an extremely high order is desired. Graphical analysis is rendered rather cumbersome by the use of these correction factors and a method has been developed whereby the work is simplified.[1]

[1] *A Handbook of Experimental Stress Analysis*, edited by M. Hetenyi, Chapman and Hall.

STEEL ECONOMY.—The Ministry of Works has published a leaflet entitled *The Design of Buildings*, which is the first of a series of bulletins for the building industry which are intended to effect economies in the use of steel. Design with this aim in view is discussed in the leaflet.

15MW Gas Turbine Alternator Set at Trafford Power Station

The first gas turbine alternator set to be commissioned by the British Electricity Authority is the experimental 15MW open compound cycle unit which went on load at Trafford power station on August 6th. It was built by Metropolitan-Vickers Electrical Company, Ltd., and installed in an engine-room adjoining the 60MW steam section of the power station. Some details of the new plant are given herewith.

THE newly commissioned 15MW gas turbine alternator set at Trafford power station should make a useful addition, particularly during peak load hours, to the existing generating capacity of 60MW on the steam side of the station. The steam sets consist of a 30MW Parsons turbo-alternator which was commissioned in 1940, and a 30MW Metropolitan-Vickers turbo-alternator commissioned in 1947. Steam for these sets is generated in four Babcock and Wilcox boilers—two evaporating 150,000 lb of steam per hour each, and two evaporating 220,000 lb of steam per hour each, the steam conditions being 425 lb per square inch at 825 deg. Fah. All the boilers are equipped with chain grate stokers and the boiler auxiliaries are operated under the Metropolitan-Vickers "unified" control system.

General views of the 15MW gas turbine installation are shown in Figs. 1 and 2 and the arrangement of the equipment is given in Fig. 3.

The gas turbine plant operates on an open compound cycle and Fig. 4 is a diagram of the air, fuel and gas flow. It will be seen that the plant consists of a low-pressure compressor, an intercooler, a high-pressure compressor, a heat exchanger, a main combustion chamber, a high-pressure turbine, a reheat combustion chamber and a low-pressure turbine, the exhaust from which passes back through the heat exchanger before being discharged to the chimney stack.

The low-pressure turbine is directly coupled to the low-pressure compressor and to the 15MW generator; it runs at a constant speed of 3000 r.p.m. under the control of a speed governor regulating the fuel admission to both combustion chambers. Both the high-pressure turbine and the high-pressure compressor are coupled together and run at a speed determined by the load conditions, 5500 r.p.m. at full load. The combined length of the two units is 80ft and, with an intervening space of 16ft occupied largely by the reheat chamber, the overall length is 96ft.

It will be appreciated that this gas turbine plant is largely experimental and detail modifications will no doubt be made in the light of operating experience. The plant is designed for a gas inlet temperature to both turbines of approximately 1200 deg. Fah. and an overall pressure ratio of 10 to 1. Before the incoming air is admitted to the low-pressure compressor it is passed through a "Precipitron" electrostatic filter, which removes solid impurities that might impair the efficiency of the compressor blading. On leaving the heat exchanger the exhaust gases enter a 250ft stack built of reinforced concrete.

At first gas oil will be used as the operating fuel but later it is hoped to modify the plant to use heavier grade oils. On starting, the high-pressure line is rotated by a 400 h.p., a.c., direct-coupled starting motor, and fuel is gradually admitted to the main combustion chamber; the motor is disengaged on reaching a speed of about 3000 r.p.m. During this time the air drawn through the low-pressure compressor and the gas discharge through the low-pressure turbine slowly rotate the low pressure line and, as fuel is gradually admitted to the reheat chamber, the speed of the low pressure line and the generator increases to 3000 r.p.m. During idle running the high pressure line runs at about 3000 r.p.m.

Compressors and Turbines

Both compressors are similar in general construction, the low-pressure machine having fourteen stages and the high-pressure fifteen stages. The stators are of fabricated construction and the rotors are high-tensile chrome-alloy forgings. The stainless steel blades are held in circumferential serrated grooves.

The high-pressure turbine has two expansion stages. The stator and diaphragms are of austenitic material and the nozzles of both stages of "Nimonic 75" alloy. The rotor is a molybdenum-vanadium forging having blades of "Nimonic 80A," held in axially serrated grooves.

The low-pressure turbine, which has six stages, has an austenitic stator with diaphragms and nozzle blades for the first three stages of like material and for the last three stages of ½ per cent molybdenum steel. The low-pressure rotor body (Fig. 5) is a molybdenum-vanadium forging with axially serrated blade roots, holding blades of "Nimonic 80A" for the first row, of austenitic steel for stages two and three, and of ½ per cent molybdenum steel for the final three stages.

Each compressor is connected to its turbine by a flexible plate coupling. A semi-flexible coupling connects the low-pressure compressor and the alternator.

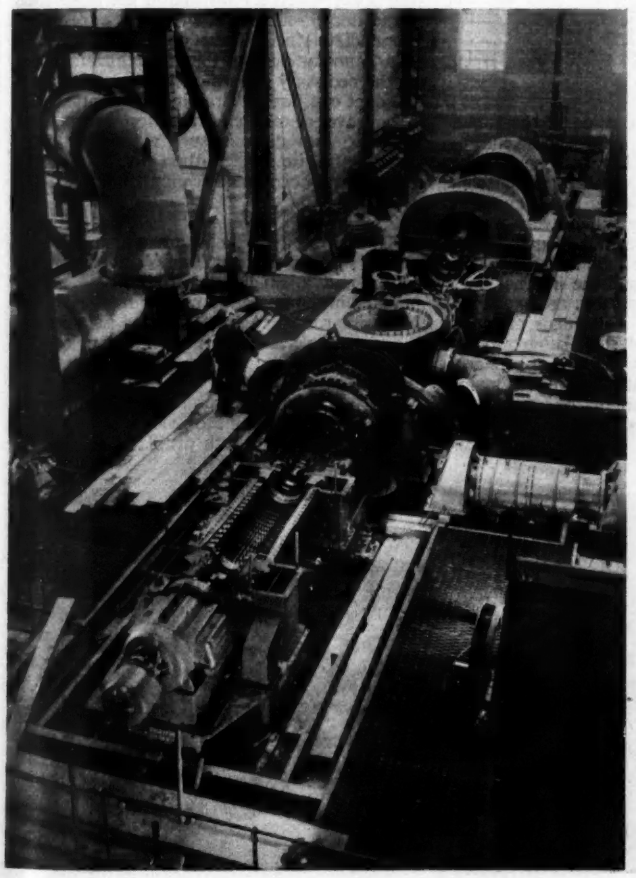


Fig. 1—15MW Gas Turbine Set during Erection at Trafford Power Station

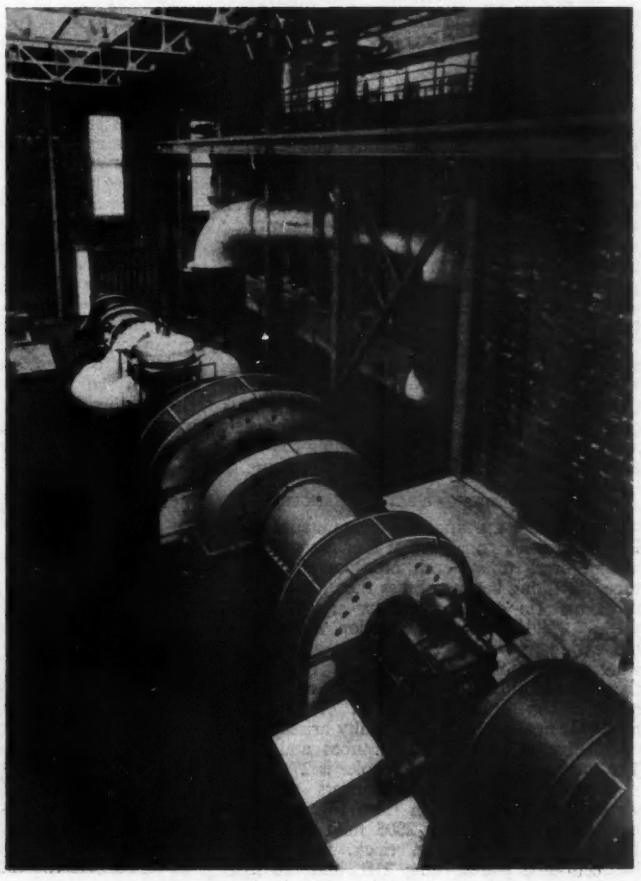


Fig. 2—Gas Turbine from L.P. End

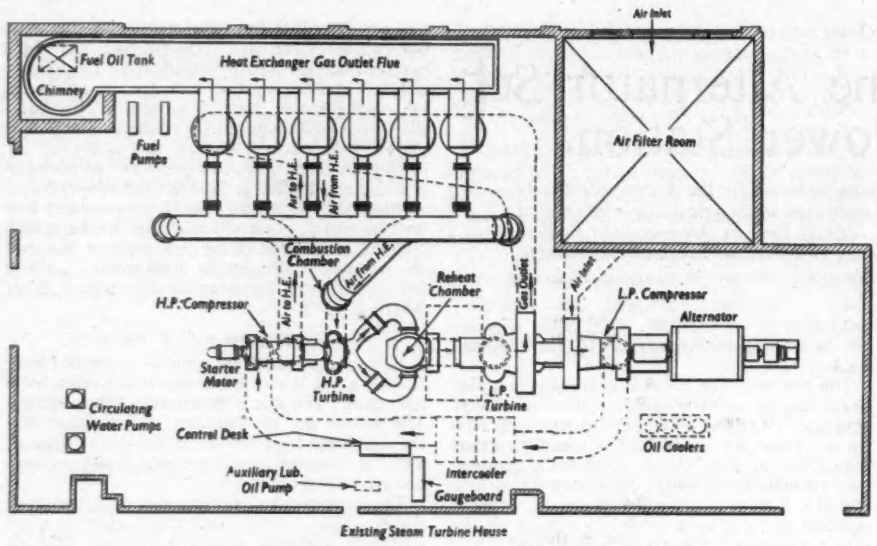


Fig. 3—General Arrangement of Gas Turbine Alternator Set

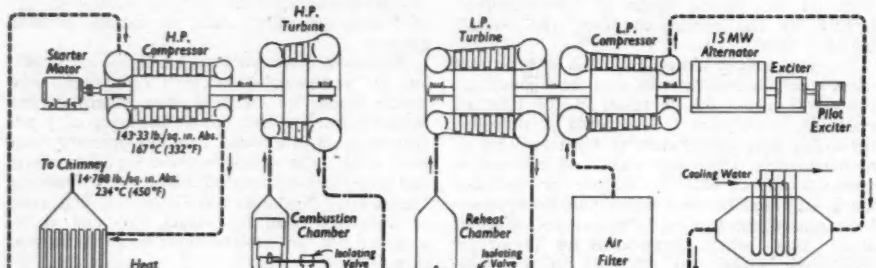


Fig. 4—Flow Diagram for Gas Turbine Set

The whole plant is lubricated by means of a gear-type pump, which is mounted on the inlet end pedestal and is gear-driven from the main shaft of the low-pressure turbine. For starting up and for barring after shutting down, an auxiliary lubricating oil pump is provided; it is motor-driven and has the same capacity as the main pump. When the speed of the low-pressure line is sufficient the auxiliary pump automatically cuts out and the main pump meets the duty.

Barring of the high-pressure line is done by the starting motor. The low-pressure line is barred by a separate barring motor mounted on the turbine pedestal and driving on to the shaft coupling through a double reduction worm gear. A jacking pump is installed to supply the bearings of the l.p. line during slow-speed barring.

Intercooler and Heat Exchangers

Between the l.p. and h.p. compressors there is an intercooler consisting of four nests of wire-wound brass tubes, each nest containing 232 tubes 12ft long between brass tube plates. The tubes are 1in outside diameter and 18 s.w.g. thick. Welded steel construction is used for the casing and the water headers are of cast iron. A two-flow circulation is maintained through the tubes, the water inlet and outlet being at the top of the cooler. The bottom header is floating so that difficulty arises owing to relative expansion of the tubes and shell. The total weight of the intercooler is 27 tons.

There are six heat exchangers mounted vertically, as can be seen from Fig. 6. Each heat exchanger contains 2005 mild steel tubes 1in O.D. and 16 s.w.g. thick, the distance between tube plates being 21ft, and the total tube surface 66,100 square feet. The hot gas flows through the tubes and the high-pressure air to be heated over the outside of the tubes. This arrangement closely approaches contra-flow, the air entering the top and leaving the bottom of the casing, and the hot gas entering the tubes at their bottom ends and leaving at the top. An internal liner fitted with spaced rings, shaped to register with the outer tubes, confines the air flow in the tube nest; a gland is fitted between the shell and the internal liner for the same purpose. The tubes are expanded into steel tube plates at both ends, relative expansion of the tubes and shell being met by means of a gland between the tube plate and shell at the top end. Tube spacing is maintained throughout the length by transverse corrugated strips (Fig. 7), a construction which also facilitates replacement of individual tubes.

The heat exchangers have an overall height of 24ft 5in with a diameter of 5ft and weigh 23 tons each. They are each mounted on four radial foundation guide plates to allow for expansion while maintaining their exact location.

Combustion Chambers

The main combustion chamber is mounted in a vertical duct (on the right of Fig. 6) connecting the top heat-exchanger air bus-main and the high-pressure turbine inlet. It consists essentially of an outer casing of mild steel some 42in in diameter and an inner primary chamber wall of stainless steel. The inlet air is admitted to and gradually mixes with the products of combustion through a series of apertures in the inner wall. The fuel jet operates with down-stream injection and consists of four main burners and one auxiliary or idling burner, the latter being sufficient to keep the plant in idle operation.

In the centre of Fig. 6 is the reheat chamber, which is constructed differently from the heat exchanger because of the higher inlet gas temperature. The gas is caused to swirl as it enters the main cylindrical body of the chamber through two side openings; the release of this rotational motion causes effective mixing of the combustion products with the incoming gas. Only one burner—a combined main and ignition jet—is used in this chamber.

Ducting

All ducting between the main combustion chamber and the high-pressure turbine and between the reheat chamber and the low-pressure turbine is lagged both internally and externally.

In large gas turbine installations one of the major difficulties is that of providing adequate flexibility in the large diameter ducts. They are often of considerable length and, besides being subject to extreme change of temperature, they have to allow for considerable axial movement of the plant components. For the Trafford installation, where a duct diameter of 54in is used, the manufacturers introduced a new design of flexible expansion piece (Fig. 9). It consists essentially of two annular discs of steel plate, which are pivoted at the inner edges to the duct itself and at the outer edges to an intermediate ring. These discs form a flexible collar, annular discs of thin flexible metal effecting the necessary gas seal at the pivoting points. The duct can flex by straining the annular discs to concave or convex formation as required. The maximum stress in such a construction is, for equal flexure, far less than would occur in a conventional corrugated section.

Fuel System

The fuel storage tanks are situated on the remote side of the canal adjoining the power station and a smaller service tank is accommodated in the foundation of the stack adjoining the engine-room. A float-operated switch maintains a suitable level of fuel in the service tank by starting and stopping a motor-driven pump near the storage tank.

The fuel system is very simple and flexible from the control point of view. It has been designed for use on both distillates such as gas

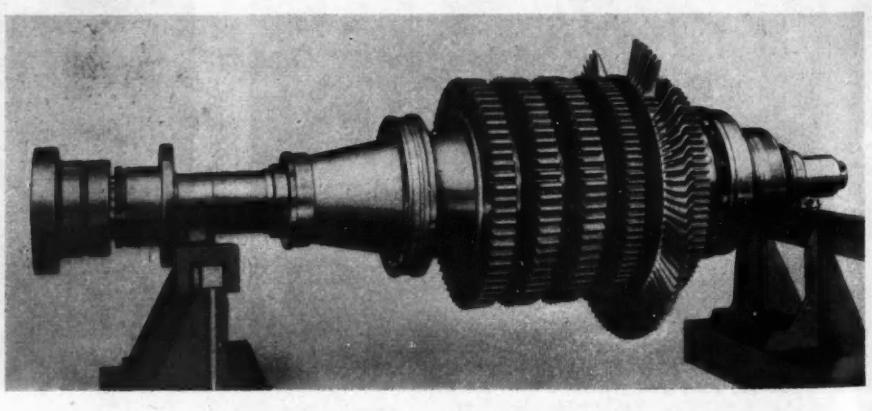


Fig. 5—Rotor of L.P. Turbine partly bladed

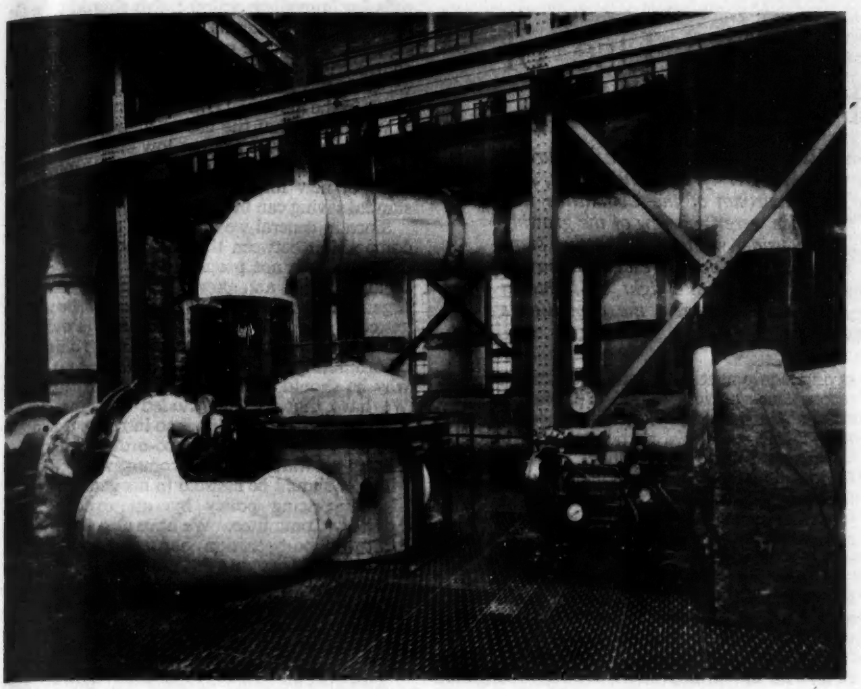


Fig. 6—Reheat Combustion Chamber with H.P. Turbine on the left

oil and on pre-heated residual fuels, and an outline of the arrangement is given in Fig. 4.

From the service tank fuel flows by gravity through filters to two Towler motor-driven fuel pumps. Each pump is capable of delivering 1686 gallons per hour against a pressure of 1000 lb per square inch. One pump alone is sufficient to meet the requirements of the plant, the other being in reserve brought into service automatically should fuel pressure drop.

From the fuel pumps the fuel passes through two overspeed emergency trip valves, one for each turbine. These trip valves follow normal steam practice, the fuel valves being held open by lubricating oil pressure and tripped by the release of this pressure in the event of overspeed detected by either of the turbine governors.

From the emergency trip valves the fuel passes to the temperature-control fuel valve, the purpose of which is to regulate the fuel admission in such a way as to prevent excessive gas temperatures in the turbines. The fuel then passes to the constant-speed governor valve, which is of the balanced needle design and is operated directly from the speed governor arm, the considerable force available rendering the use of a relay mechanism unnecessary. The governor is gear-driven from the low-pressure turbine spindle and is mounted on the inlet end pedestal near the main oil pump. The needle of the fuel valve is profiled to give a straight line relationship between the load and governor arm travel. Speeder gear is incorporated for operation both by hand and remote electric control.

From the governor valve the fuel divides, one line going to the main combustion chamber and the other to the reheat chamber, the fuel in each instance passing through flow meters which can, however, be isolated when residual fuels are used. The main fuel supply to each chamber passes through a hand control valve and an isolating valve, a tapping upstream from the hand control valve of the main chamber supplying fuel to the auxiliary burner. Between these valves connections are taken to pressure gauges fitted with electrical contacts, which are so arranged that, if the hand valves are in the open position during an attempted start, the build-up of pressure will cause the contacts to break and render the start ineffectual; thus the set cannot be started with the hand valves open, which would result in premature admission of fuel to the main burners. To simplify the control system further these hand valves are mounted on the control desk (Fig. 8), and thus remote control mechanisms are obviated. The isolating valves are controlled by magnet valves, which, when switched on, admit pressure oil to the operating servo-cylinders and thus open the isolating valves. The switching off of the magnet valves and the closing of the isolating valves release the fuel in the pipe-line to the drain tank.

A number of interlocks are provided to safeguard against a wrong sequence of starting operations. Thus, for barring, the starter motor is interlocked with the auxiliary oil pump and one of the circulating water pumps, so that the starter motor cannot run unless these two pumps are running. For starting, the starter motor is interlocked with the electrostatic air filter, the l.p. line barring motor, one of the main fuel pumps and one of the circulating water pumps. A further interlock ensures that the reheat chamber cannot be lit before the main chamber.

Alternator

The a.c. generator is rated at 17,650kVA, 6·6kV, three-phase, 50 c/s, and is direct coupled to the gas turbine. It is of Metropolitan-Vickers' standard construction with a welded stator frame. The stator has an involute winding and a closed-circuit ventilation system is provided with a water-cooled air cooler mounted in the foundation below the machine. Cooling air is recirculated by means of fans mounted on the ends of the rotor.

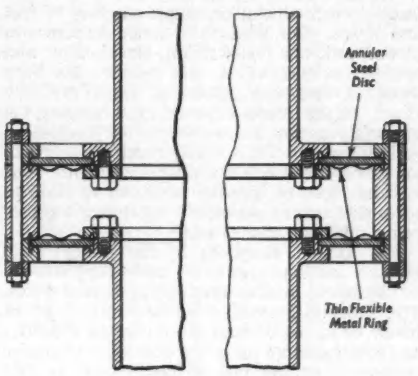


Fig. 9—Expansion Joint

Excitation is obtained from a main exciter and a pilot exciter, both direct coupled to the main generator shaft. The rotor sliprings are situated one at each end of the rotor.

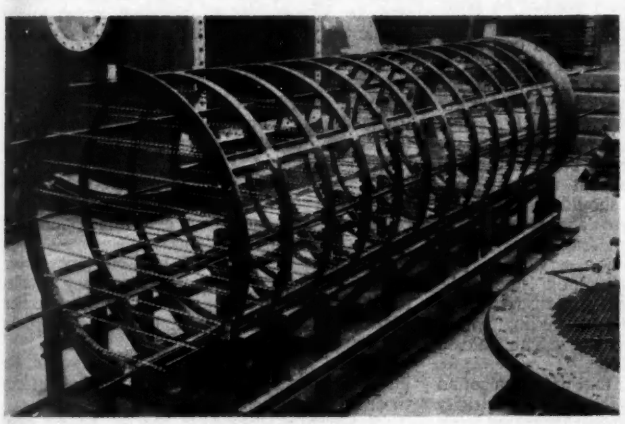


Fig. 7—Inner Frame for Heat Exchanger Tube Nest

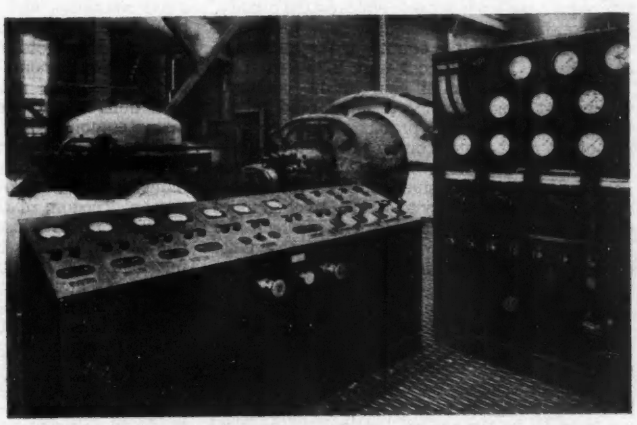


Fig. 8—Combustion Chamber and L.P. Turbine seen from Control Desk

---

Ministry of Supply Appointment.—Air Commodore F. R. Banks, C.B., has been appointed principal director of engine research and development at the Ministry of Supply. He is to be responsible for the Ministry's research and development programme for aero-engines. Air Commodore Banks, who is fifty-six, has been specially released by the Associated Ethyl Company, Ltd., of which he was technical manager, to take up this appointment. During the war, Air Commodore Banks served successively as director-general of engine production and director of engine research and development in the Ministry of Aircraft Production.

National Policy for the Use of Fuel and Power

The Committee on National Policy for the Use of Fuel and Power Resources, which was appointed in July, 1951, by the then Minister of Fuel and Power, Mr. Philip Noel-Baker, has issued its report. The chairman of the Committee was Viscount Ridley, C.B.E., and the terms of reference were " in view of the growing demands for all forms of fuel and power . . . to consider whether any further steps can be taken to promote the best use of our fuel and power resources, having regard to present and prospective requirements and in the light of technical developments." The following abstracts from the report give the committee's general conclusions and principal recommendations.

General Conclusions

THE prosperity of the United Kingdom rests on its flourishing industry and world-wide trade ; both depend on ample supplies of fuel and power. But, since 1939, under the pressures of war, post-war recuperation, export drive and renewed defence effort, the country has been short of fuel and power—at times critically short. In the future, however, as in the past, the nation's progress and well-being will depend on fuel and power ; it is vitally necessary to make the fullest effective use of what is available. Our task has been to consider what can be done to solve this urgent problem ; we bring together below our main conclusions.

The United Kingdom at the present time remains acutely short of coal—supplies are insufficient to meet all demands at current prices. This shortage is masked by the " rationing " of house coal, the allocation of coal to industry, and the existence of price control. Domestic consumers cannot buy as much coal as they would like to purchase, industrial users do not always receive the qualities of coal they would prefer, and coal exports are restricted to a level far below what could profitably be sold abroad.

These are serious results. The " rationing " of domestic consumption inflicts inconvenience and even hardship on some people, and has provoked a switch to the unrationed fuels (mainly electricity and gas) which must be in some degree uneconomic, does not reflect consumers' preferences, and adds to the strain on gas and electricity capacity. The restriction of supply which necessitates industrial coal allocation must have some adverse effect on the quality, if not on the quantity, of industrial output. But the greatest loss to the country is the restriction of exports. If more coal were exported there would be a substantial gain in the country's foreign exchange earnings ; this would relieve the balance of payments problem, which remains one of the most acute economic difficulties facing the United Kingdom to-day. In addition, having more coal of suitable types for export might enable the country to secure larger supplies of scarce foods and raw materials which the exporting countries will only trade against equally scarce goods—like the types of coal they need.

Thus there is a pressing need to make good use of the coal supplies the country has available. But fuel is often used very wastefully. We have considered at length what can be done to remedy this state of affairs. We do not recommend the stiffening of house coal " rationing "—indeed, we hope to see the end of " rationing " as soon as ever coal supplies and competing claims permit. The majority of us do not believe that any system of industrial fuel " rationing " is practicable, and we should like to see industrial coal allocation end with house coal " rationing." We all recognise the importance of the price of coal ; four of us believe that it should be increased, and that this would provide an incentive to economy ; the other four discount this effect and believe that a price increase would in other ways be harmful.

We all strongly support certain positive measures to improve fuel use. In the domestic field, we should like to see developed and widely used new improved types of open fire to replace existing inefficient grates which, in twelve million households, are a major source of coal waste. We recommend incentives to owners and occupiers of houses for the installation of fuel-saving equipment. On the industrial side we recommend a very large expansion of fuel efficiency advisory service, and a new approach to securing the active participation of industry. We also recommend incentives to industrialists for installing fuel-saving equipment, and measures for improving the standards of stoking. We look to Government Departments, local authorities and other public bodies to give the community a lead in the efficient use of fuel.

Although in Table II we have made tentative estimates of fuel consumption ten years hence, and indicated that on present trends there may be difficulty even then in balancing the coal budget, we cannot make any trustworthy estimate of how far the various measures we have suggested for improving fuel efficiency will go towards closing the possible gap in the country's fuel and power supplies. Nevertheless, we are convinced that the combined effect of all the measures we have proposed would be a marked improvement in the fuel efficiency of the country.

It has been suggested to us that the present balance between the use of different fuels means waste of coal and capital resources. We find that the case is often grossly exaggerated, and we have not recommended that the Government should enforce any changes in the pattern of the fuels used for any purpose by any type of consumer.

There has recently been some controversy in the press and elsewhere, between protagonists of the gas and electricity supply industries, claims being made that the one fuel or the other represents the most efficient use of coal and other resources, and should therefore be given preference for various types of service. Our study of the problems involved has convinced us that any general judgment of this kind is unrealistic. The needs of consumers and the conditions of use are so varied that there are many combinations of different fuel services which may be said to be " right." We have recommended that competition between the fuel industries should continue—but that the consumers' freedom of choice should be guided by bringing prices closely into accord with the relevant costs, and by providing users with a full and objective information service on fuel and fuel appliances. We look upon the nationalised gas and electricity industries as in a sense branches of one undertaking, within which, however, competition is a valuable aid to efficiency.

We do, however, consider that there is a sound case for the drastic remodelling of electricity tariffs to differentiate between charges at peak hours, when supply is expensive, and at other times, when it is cheap. This will take time, since it means the development of methods for differentiating between peak and off-peak use. We suggest that practical trials should be put in hand immediately.

In suggesting tariff changes to favour off-peak rather than peak use of electricity, we are not attempting any judgment between gas and electricity. We are impressed with the need for electricity supply capacity to overtake demand, which we expect to go on increasing ; our suggestions on tariffs do not mean that we question the need for continued investment in new electricity plant, both to meet demand and to replace old and inefficient plant which is a drain on the country's coal supplies. The shortage of electricity supply capacity, second only in seriousness to the shortage of coal itself, calls for immediate action ; this should take the forms of revised terms for making " standby " supplies, immediate practical trials of peak-load controlling and measuring systems, and the wider application of suitable maximum demand tariffs in the industrial and commercial fields.

We believe that the use of high-grade coal by the railways at the present low efficiency should not continue, and we recommend intensified trials of new forms of motive power. A substantial saving can in time be made in this field.

Since in general we favour the maintenance of competition between the fuel and power industries, we have not proposed any central control of all the fuel and power services by any new organisation such as has frequently been suggested. The Minister of Fuel and Power has the statutory duty of generally controlling and co-ordinating fuel supplies, and we see no reason why he should share it with any new authority. We have, however, concluded that the adjustment of prices and tariffs is so intricate a process, and so important for the co-ordination of fuel use, as to warrant our recommending that the Minister should be assisted in his general control of fuel pricing policy by an expert Tariffs Advisory Committee. We have also found scope for more co-operation between the fuel and power industries in the production and distribution of their services, and for this purpose we have proposed the establishment of a Joint Planning Board on which the fuel industries could concert policy, with the assistance of the Minister.

Although we do not consider that new methods of using conventional fuels more efficiently, or methods of exploiting sources of energy not at present used, can have much effect in the next few years, we believe it to be of the utmost importance that research and development directed to these ends should continue to be prosecuted with the greatest vigour, and we look to the Minister of Fuel and Power to provide the necessary stimulus.

The fuel shortage is likely to continue for some years to come, although it may be temporarily eased by transient changes in the level of industrial or commercial activity. But the need for increased fuel efficiency and the duty of conserving our fuel resources will remain permanently. Our recommendations depend for their effectiveness on the willing and continuing co-operation of all fuel users, and those responsible for controlling fuel and power policy should lose no opportunity of bringing home to the public the supreme importance of fuel economy.

Recommendations

Forty specific recommendations are set out in the report. Those recommendations to which the committee attaches special importance are given herewith.

(1) New standards of performance based on achieving a room efficiency of the order of 40 per cent with coal should be determined for solid fuel room heating appliances.

(2) The production of high-efficiency open fires of " utility " pattern capable of easy installation in existing fire openings, and with convection heating and a restricted throat, should be encouraged.

(3) The production of simple devices for insertion in existing flues to restrict the chimney throat should be encouraged.

(4) Financial incentives should be provided for the installation of fires of the new standards and for improved insulation of houses.

(5) There should be a great increase in the service for providing industry with advice on fuel efficiency.

(6) The Minister should invite industry to set up an organisation to provide a greatly increased fuel efficiency advisory service for industry.

(7) The present scheme for Government loans for approved fuel saving installations should be amplified, on more attractive terms.

(8) Stokers should be encouraged to raise their efficiency by arrangements for improving their status.

(9) Government Departments and other public authorities should take the lead in promoting fuel efficiency.

(10) The Railway Executive should plan for

increased fuel efficiency, and should accelerate trials of new forms of traction.

(11) Electricity tariffs should discriminate in charges between peak and off-peak use.

(12) Immediate steps should be taken to make extensive practical trials of the various methods of measuring or controlling the consumption of electricity at system peak hours.

(13) The Minister of Fuel and Power should be assisted in his general control over the price policies of the nationalised fuel and power industries by the establishment of a specialised Tariffs Advisory Committee.

(14) The Minister of Fuel and Power should establish a Joint Fuel and Power Planning Board.

The Committee

The chairman of the committee, Viscount Ridley, C.B.E., was a member of the former Fuel and Power Advisory Council (the Simon Committee), which in 1946 reported on domestic fuel policy. The other members of the committee were: Mr. Lincoln Evans, C.B.E., general secretary of the Iron and Steel Trades Confederation; Mr. N. W. Gardiner, technical director of Huntley and Palmers, Ltd.; Sir Claude Gibb, C.B.E., F.R.S., chairman and managing director of C. A. Parsons and Co., Ltd.; Professor W. R. Hawthorne, Professor of Applied Thermodynamics at Cambridge University; Professor W. A. Lewis, Professor of Political Economy at Manchester University; Mrs. M. McIntosh, tutor in sociology at Bedford College, University of London, and member of the London County Council; Miss M. R. Schofield, housing manager of Stoke Newington Borough Council.

A "Cosmotron" at Brookhaven National Laboratory

(By Our American Correspondent)

The construction phase has recently been completed of the particle accelerator known as the "Cosmotron" at the Brookhaven National Laboratory, at Upton, Long Island, New York, which is shown in the accompanying illustration. The purpose of this accelerator, which is now in its preliminary testing stage, is to speed up protons until they acquire an energy in excess of 2000MeV, an energy available heretofore only in cosmic rays. The protons can be directed against various targets, such as blocks of copper or graphite, and the results of these collisions studied; or they can be used to produce other nuclear particles, such as neutrons or gamma rays. It is said that the cosmotron will produce particles with over five times the energy of existing accelerators. Once every five seconds, a pulse of protons is injected into the cosmotron from a 3·5MeV electrostatic Van de Graaff accelerator. A doughnut-shaped magnet of 75ft outside diameter then forces the protons to travel in almost circular paths within the magnet gap, which is a notch 36in wide and 9½in high in the periphery of the doughnut. Each time these protons make one revolution around the magnet, they will be given a small increase in energy (about 1000V) by a radio-frequency transformer. The magnetic field increases continually so that, as the protons gain energy, they are still kept on approximately the same circular paths. After some 3,000,000 revolutions and after a travel distance equivalent to five times round the world, the particles will have acquired full energy, a process taking about one second. The magnet itself is composed of 288 flat steel blocks, each 8ft high and 8ft wide. Each block weighs about 5 tons and consists of 12½in laminations insulated from each other. The magnet is energised by a copper busbar carrying a peak current of 7000A and weighing about 65 tons. The copper bars are hollow, for the circulation of cooling water. The electrical energy for the magnet is supplied by a 21,000kVA motor generator flywheel unit. A set of twenty-four large ignitrons serve both as rectifiers, to supply direct current to the magnet, and as inverters, whereby the major part of the magnetic energy is returned to the flywheel for storage for the next operation. Since the presence of air would cause the protons to lose energy, they must travel in an evacuated stainless steel chamber, which rests in the magnet gap. Four large mechanical vacuum pumps situated in the centre of the ring remove most of the air, but twelve 20in diffusion pumps situated outside the ring are needed for final evacuation.

International Astronautical Congress at Stuttgart

The Third International Astronautical Congress was held in Stuttgart from September 1st to 6th, and was attended by delegates from most European countries, from the U.S.A. and the Argentine.

Many papers concerning the fundamental problems in astronautics comprised the technical sessions of the Congress and a large proportion were concerned with immediate engineering and scientific problems. Amongst the German papers was one concerning the development of the "V-2," and another by Bachem, which gave technical details of the vertically launched interceptor rocket aircraft, the Watter.

"Optimising" of components, such as the combustion chamber design, so that the pressure gives minimum gross weight, was discussed. This pressure was found by H. H. Koelle (Germany) to be a flat optimum between 50 and 80 atmospheres. F. L. van der Wal (U.S.A.) presented a paper showing the use of dimensional analysis in developing relationships which affect the weight of rocket fuel tanks, pumps, pipes, combustion chambers, and wings. It was shown that significant improvements remain to be made in reducing the weight of structural components of liquid fuel rockets, and winged vehicles of the Sanger-Bredt type need not have excessively heavy wings and control surfaces. From G. E. Janzon (Germany) came a design for a new type of propellant pump, which should considerably reduce the weight requirements for a given pressure head and pump delivery.

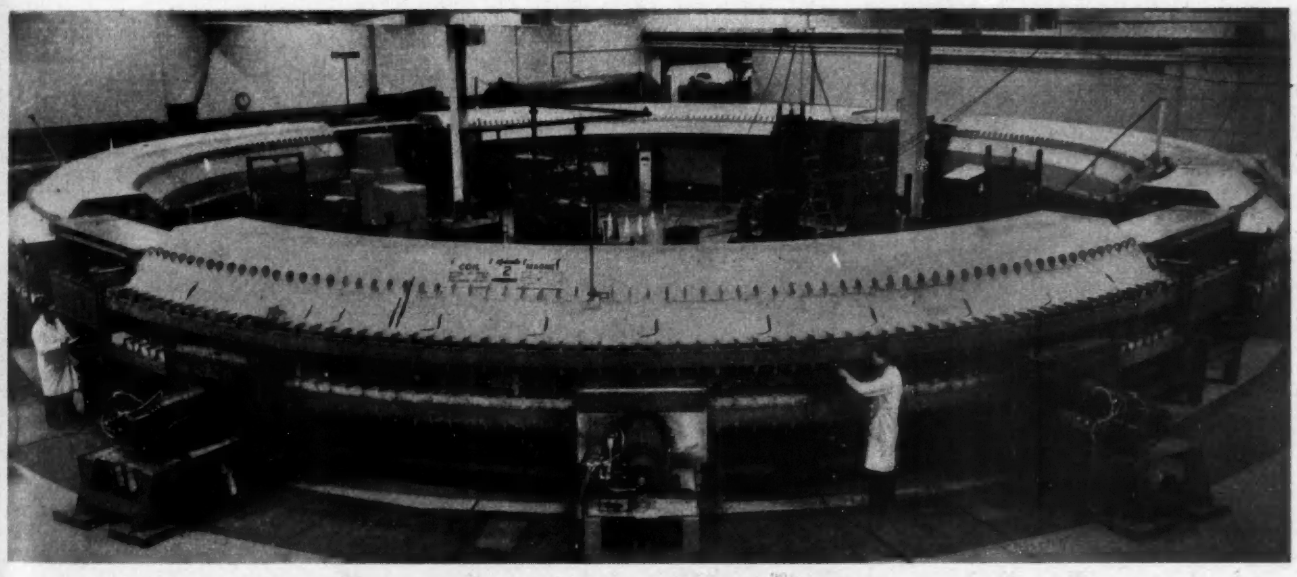
A number of papers were given by various workers concerning the biological effects of hard radiation at high altitudes and in interplanetary space. Dr. H. J. Schaefer (U.S.A.) outlined the problems to be solved. The heavy nuclei component of the primary radiation has an extremely high specific ionisation power. The low energy nuclei are the most dangerous, but we do not know how many are likely to be encountered in space because of the possible screening effect of the geomagnetic field which concentrates such cosmic ray particles at the terrestrial poles. Moreover, the action of the heliomagnetic field is a doubtful but possibly important factor. The equatorial belt would appear to be the safest one for high-flying manned rocket aeroplanes.

On the administrative side of the Congress successful agreement was obtained from all the delegates, and a constitution for the International Astronautical Federation was adopted.

A large exhibition took place at the Landesgewerbemuseum, including a "V-2" rocket, several rocket motors, models of rocket aircraft, and of the vessels for the von Braun Martian project. A film show included an interesting new American colour film of the testing and firing of the Glenn L. Martin high-altitude "Viking" rocket.

The Congress concluded with a reception and dinner at the Kursaal, Bad Cannstatt, and the speakers included the Burgomaster of Stuttgart, Professor Shulte, Dr. Sanger and several heads of delegations. Professor Shulte asked Lieut-Commander F. Durant to accept the Hermann Oberth Medal for Dr. Wernher von Braun, who was unfortunately unable to attend the Congress in person.

Launch of Inshore Minesweeper.—H.M. inshore minesweeper No. M.2001 was launched at the shipyard of J. Samuel White and Co., Ltd., Cowes, Isle of Wight, on September 3rd. The Navy Estimates for the current year show that twenty-nine of this class of vessel were in course of construction, but not launched, at the end of March last. These minesweepers are 106ft 5in in length, with a beam of 20ft 6in, and are designed to operate in shallow waters, such as rivers and estuaries. In addition to minesweeping equipment, each will mount one small gun. The main machinery of No. M.2001 is being supplied by Fodens, Ltd., Sandbach, Cheshire.



"Cosmotron" Installation at Brookhaven National Laboratory

Works of the Stirlingshire and Falkirk Water Board*

By ERIC W. DENHOLM, M.I.C.E.†

THE Carron Valley reservoir of the Stirlingshire and Falkirk Water Board covers some 960 acres and, with a capacity of 4,268,000,000 gallons, it is the largest wholly man-made impounding reservoir in Scotland and is exceeded in capacity by very few in Britain. The catchment area lies on the crest of the Scottish watershed, from which about 8850 acres drain naturally to the east and the North Sea while the remaining 450 acres drain naturally to the west and the Atlantic Ocean. This unusual site made the construction of two embankments necessary, the main embankment being at the east on the River Carron and the subsidiary embankment at the west on a tributary of the River Endrick. The main dam itself is of rather unusual design. The centre portion, carrying the overflow, is built in cyclopean masonry, faced with tinted concrete blocks, while each wing is constructed as an earthen embankment having a clay puddle centre core from rock level, a 3 to 1 pitched inner slope and a 2½ to 1 grass-sown outer slope. Both the masonry and the earthen embankments are of normal design in themselves, the unusual feature being their incorporation together in one embankment. There has been no evidence to suggest that this arrangement is other than wholly satisfactory. The depth of the water at the main embankment is 33ft 6in.

The embankment at the western end of the reservoir, known as the Randyford embankment, is 1560ft in length, or about 100ft longer than the main embankment. This subsidiary embankment is of similar earthen construction to the wings of the main dam and has a water depth of 27ft. Arrangements are made here for drawing off water to the western and sparsely populated portion of Stirling County. Of interest also is the fact that the River Endrick rises a few miles to the north of the Randyford embankment and, while the Carron Valley catchment area is at the moment somewhat over-reservoired, a further 4500 acres from the Endrick catchment can be diverted to Carron Valley reservoir by means of an intake and pipe-line. About two years ago the Board completed construction of a measuring weir on the Endrick against the time when this further supply would be required.

What is probably the most interesting feature of Carron Valley reservoir is its cost. Despite the fact that compensation from the reservoir is over 30 per cent of the estimated gross yield, there remains an available supply of fully 12 m.g.d. With a capacity of 4,268,000,000 gallons and a total cost of £210,560—which includes the construction of two embankments, the diversion of some 1½ miles of public road and the purchase of the gathering ground—the reservoir is indeed the cheapest constructed (in Britain) in the present century and this cost of less than 1s. per thousand gallons stored compares very favourably with the cost of Liverpool's reservoir at Lake Vyrnwy, constructed last century when costs were considerably lower, for approximately the same unit cost.

POST-WAR WORKS

The completion of the construction of Carron Valley reservoir coincided with the outbreak of war and the Board's further developments, required to bring the water stored in Carron Valley to the consumer, were held in abeyance, but towards the end of the war the author submitted a comprehensive report on the development of the area of supply. The proposals envisaged a number of service reservoirs within this area, these necessary adjuncts to a satisfactory distribution system having previously been neglected in favour of additional pipe-lines into the area all from one side only, namely, the west.

The need for flexibility in these proposals became very evident with the establishment of one huge new water consuming industry and the extension of another existing factory on the fringe of the Board's area of supply, but within the area supplied by Grangemouth Town Council. This latter authority had no source from which to slake the thirst of these denizens, these leviathans, which had taken up their abode with them, and were forced to turn to the Board for a bulk supply for industrial purposes. In round figures the Grangemouth Town Council now supplies 2 m.g.d. from their own works and takes 8 m.g.d. from the Board. Grangemouth has been quoted many times in the Press as being Scotland's most rapidly extending and most prosperous burgh—a position which they owe to the Stirlingshire and Falkirk Water Board.

Arrangements to proceed with the laying of some 14 miles of main from 40in to 24in diameter were made and concluded in July, 1948, and the Board sought an Order to proceed with this work and the construction of two service reservoirs, distribution mains and a large rapid gravity filtration plant of 12 m.g.d. capacity with provision for extension in the future to 20 m.g.d.

The filter plant went on to the drawing board initially in August, 1948. Tenders for the mechanical equipment and general design were called for and a contract awarded to the Candy Filter Company, Ltd., in March, 1949. The structural work was designed during that summer and a start made on construction on October 23, 1949, by the Fram Reinforced Concrete Company, Ltd., who had been awarded the building contract. The work is now in its closing stages and it is expected that it will be completed within two months.

Before the Board embarked on the construction of this filter plant it considered it essential, in view of the changes which appear from time to time in the technique of water treatment, that the plant as laid down in the first place should be as modern as possible and, secondly, that it should be as freely adaptable as possible to employ any new technique in treatment which might be considered worth while in the future.

The treatment arrangements allow for the introduction of alum and soda ash or other alkali in solution or alternatively sodium aluminate may be used if it is found to be more satisfactory and equally economical. Provision is made for lime treatment after filtration, using either hydrated lime or lump lime and in the latter case the lime will be slaked in mechanical slakers. Provision has also been made for both pre-chlorination and post-chlorination or either with, if necessary in the latter case, ammonia. Sodium hexametaphosphate can be introduced for stabilisation of pH value and provision is also made for seasonal use of activated carbon, since algal troubles have occurred from time to time at Carron Valley reservoir. The treatment plant consists of twenty-four upward-flow settling tanks operating at a vertical velocity of ¾in per minute, and twelve filters with a rating of 75 gallons per square foot per hour. From the filters the water passes into a clear water balancing tank of 2 million gallons capacity.

There are a number of unusual features about the plant, one of the most interesting being that this is probably the first large filtration plant owned by a local water authority to incorporate automatic filter washing, and, in addition, the particular arrangement used for the automatic control is an entirely new application to this work. The Board decided on this form of operation after full consideration, and, I may say, without any pressure from their engineer, who was, at that time, somewhat sceptical. Now that the design of the automatic control has reached its present stage my scepticism has disappeared and I understand that it will not be for long that this is the only plant incorporating this method of control.

One advantage of an automatic control system is that the filter gallery itself is kept clean and normally would be clear of all plant except the rate setters. The automatic control has, however, been taken one step further and the rate setters have been taken back hydraulically to the side tables so that now the filter control gallery is quite clear and the state of every filter and every operation on the plant can be seen from one point in the administration hall. Although stripped of all its controls, the control gallery will probably continue to be so styled for want of a better name.

A plant of this size would normally require, if staffed only for eight hours per day, practically continuous washing attendance over that period, but the automatic control ensures that the washing will be carried out throughout the twenty-four hours and without the assistance or otherwise of human agency.

The chemical house is on two levels, the solution tanks being on the first floor and the storage in the basement. Chemicals are handled throughout by electrical crane. The gallery alongside the filters is also on two levels, the lower level, or pipe gallery, having access to the wash water pipes and draw-off pipes, and the upper gallery, the control gallery just mentioned, giving a view of the filters in operation.

The administration building is on three floors. The ground floor or basement houses the pumps which lift filtered water for washing from the filtered water channel to the tank in the roof, and also the air blowers for air agitation of the sand. These items of plant are housed in a separate room mainly to reduce transmission of noise. The remainder of the downstairs floor is laid out as a workshop area, but it also houses the milk of lime tanks and lime saturator on one side and the standby generator on the other side.

The main entrance leads into the first floor, which takes the form of the administration hall in the centre of which are grouped the automatic sequencing cabinet, the side tables containing all the normal filter flow indicators and clarity bowls and the main instrument panel giving complete records of flow through the plant, pH values, chlorine residuals, &c. The main instrument panel is also equipped with a very full warning system to warn the plant operators when anything goes wrong with the plant. This warning system is transferred to one of the cottages at night.

With the plant being manned only for a portion of the twenty-four hours its proper functioning depends on the filters being contantly set to give the correct average rate of flow throughout the twenty-four hours, and, with a relatively small clear water storage tank, there is not a very great margin to work on. To meet this position the plant has been arranged to shut down automatically and, when the clear water tank reaches its top water level, water will be discharged into a float well in the machinery room in the basement of the administration building. The float which operates in this well controls the modules at all the filters so that when the clear water tank fills the filters will automatically shut down.

The shutting down of the filter outlets will cause the water level to rise both in the filters and in the settled water channel. This channel in turn communicates by a 6in pipe with the float valves at the inlet of the plant, causing the supply at the inlet to be shut down. In case anything should go wrong with the shut-down arrangements overflows are provided at the settling tanks and at the clear water tank to ensure that the plant will not be flooded.

* Abstracts from a] paper presented at the annual conference of the British Waterworks Association.

† Engineer and manager, Stirlingshire and Falkirk Water Board.

The Foil Strain Gauge

WE were recently able to see a strain gauge using a strain-sensitive resistance foil printed into a thin lacquer film which has been recently developed by Saunders Roe, Ltd., East Cowes, in conjunction with Technograph Printed Circuits, Ltd., 32, Shaftesbury Avenue, London, S.E.15. Saunders Roe, Ltd., has explained that arising out of its extended development trials on helicopter rotors the conventional wire strain gauge was found unsatisfactory. The company was measuring a number of dependent variables such as rotor and intermediate shaft torques, bending lift and drag forces on the rotors, and vibrations in control linkages, in all of which the failure of a single wire gauge might entail stopping the rotor completely.

The major weakness of this kind of gauge is the structural discontinuity at the junction of fine resistance wire to the soldering tags. It is virtually impossible to inspect such a microscopically small weld in production, so that the manufacturer can only state that there is electrical continuity through the complete gauge. He is unable to criticise the soundness or otherwise of this joint. This discontinuity is vulnerable

mechanically and electrically ; for instance, in the presence of slight moisture electrolytic action may easily occur, which eventually destroys the joint. Clearly, therefore, if it were possible to modify the gauge structure in such a way as to avoid this discontinuity, then a significant contribution to improved reliability would be achieved.

The wire gauge is wound from extremely fine resistance wire, the diameter of which rarely exceeds one-thousandth of an inch and is very often less. The winding is sometimes done on a jig and cemented to a thin paper backing, or alternatively wound as a coil on a paper former which is then flattened and the whole cemented to paper backing. Either method calls for a high degree of skill and manual dexterity from the operator. The next stage in manufacture is an even more exigent process ; the ends of the fine wire have to be soldered or spot welded to relatively substantial lead-out wires or soldering tags to which are joined eventually the connecting wires for the electrical circuits of the strain measuring apparatus. After this spot welding process the gauge is reinforced with one or more additional strips of paper to provide a reasonable degree of mechanical stability.

It became clear to Saunders Roe, Ltd., that some new approach to the problem was necessary, as it seemed impossible to retain the fine resistance wire and still avoid the discontinuity if satisfactory electrical connections in the field were required.

Attention was then turned to the possibilities of the printed electric circuit art. All known forms of printed circuit were rejected as unsuitable with the exception of a grid pattern of lead foil on "bakelised" paper which had been developed by Technograph Printed Circuits, Ltd., as part of an experimental aircraft icing detector. Saunders Roe consequently submitted a specification to this company, and after exhaustive tests the advantages of the gauge exceeded expectations.

The following advantages of this gauge were advanced by Saunders Roe, Ltd. Liberated from wire and paper it has been possible to mount the strain sensitive resistance foil on to a very thin lacquer film of good mechanical and electrical properties. Thus the transmission of strain from the specimen to the gauge is performed far more efficiently than in the case of the wire gauge in which there are intervening layers of paper. The wider sections at the ends of the fine grid also assist in efficient transmission of strain. The combination of these two virtues by themselves naturally improve the gauge performance over the best that can be expected from a wire gauge.

It has another important advantage in that the ratio of contact surface area of the resistance element to volume is very high for the foil gauge. For the wire gauge, because of the circular cross section, it is at a minimum. Thus the heat dissipation characteristic of the foil gauge is much superior, enabling the permissible working current to be many times that of the wire gauge. The sensitivity of a gauge in terms of electrical output per unit strain is directly proportional to current in the gauge, and consequently the foil gauge may be used successfully in applications where high sensitivity is a prime requirement.

A number of incidental advantages are stated, namely its thinness and flexibility, the ease of application, the simplicity of waterproofing techniques, and the fact that once properly mounted it is much less vulnerable to damage through accidental mishandling. In addition, shapes and patterns of gauges may be produced which would be impossible with wire construction.

ASLIB NORTHERN BRANCH.—The Northern Branch of Aslib is arranging a one-day conference, which will be held in the Guildhall, Kingston upon Hull, on Thursday, October 2nd, beginning at 11 a.m. Mr. Leslie Wilson, the director of Aslib, will open the proceedings with an address entitled "Aslib : What It Is and What It Does," which will be followed by a talk on "The Use of Aslib Facilities," by Dr. G. M. Dyson, F.R.I.C. At the afternoon session, beginning at 2.30 p.m., Miss J. Binns will speak on "Industry and the Public Library in Kingston upon Hull," and Mr. D. J. Foskett on "How to Start an Industrial Library." On the day after the conference, October 3rd, delegates will have the opportunity to visit the works of various local firms.

Progress in Aeronautical Science and Engineering*

By Sir BEN LOCKSPEISER, K.C.B., F.R.S.

This presidential address (Section G), by Sir Ben Lockspeiser, at the Belfast meeting of the British Association, commenced with a broad review of the early development of aviation and went on to discuss the problems which have brought about the airframe profiles of to-day. One section dealt entirely with propulsion units for aircraft and another discussed some metallurgical aspects in aircraft design. The paper concluded with some comments on runway and airport construction and the future influence of the helicopter and the flying boat. The early history and the section on propulsion have been omitted from this abstract.

THE aeronautical engineer uses the term "clean" to signify design excellence, and if we wish to understand what has happened in the air during fifty years we might take this criterion as a starting-point and ask what it implies. A clean design is one of low air resistance, or drag, as it is usually called. This is obviously of the first importance because the work done in level flight between two points is a product of the drag and the distance. The less the drag the smaller the engine thrust required. And since drag varies with air density and therefore decreases with altitude for any given incidence, it pays, over long distances, to fly as high as possible consistent with the load to be carried and the power characteristics of the engine.

Aerodynamic drag is quite a complicated affair, but certain things are obvious from the start. A fixed undercarriage, carried in the airstream creates drag, contributes nothing to lift and is a plain liability on the engine. So also are external struts and bracing wires, and, in fact, any parts of the structure that need not be exposed to the air stream. It is the business of the aeronautical engineer to get rid of drag from these causes. Indeed, as the first step to progress he was obliged to do so. He tucked the undercarriage away after take-off. He turned from biplanes to monoplanes and eliminated struts and wires, leaving only external wing supports. These, too, disappeared when his increased knowledge of structures, and the production of better materials, brought into being the cantilever wing. He enclosed the cockpit and mounted the engines in nacelles. Now he has buried the engines in the structure, and virtually nothing remains to-day of drag from unnecessary excrescences.

But a clear design means something more than absence of unnecesary projecting parts. It implies certain standards of excellence in its shape and lines—streamlined in fact, and the lines we speak of are lines of air flow, which, could they be made visible, as they can be experimentally by means of smoke, would be seen, in a perfect shape, to bend smoothly and flow snugly round curved surfaces of the structure, leaving no turbulent wake. Any departure from the ideal aerodynamic shape promotes the breakaway of the air flow from the surface and the formation of large-scale eddies of turbulence. This churning up of the air is sheer waste, and the power to produce it makes an unnecessary call on the engine. How large it was and how great the savings of power which would be possible if profile drag were reduced to its ideal minimum were first pointed out by Melvill Jones in 1929. His lecture on the subject was first regarded as an exercise in idealism, but something approaching what Melvill Jones foretold was accomplished within twenty years.

The other source of drag, known as induced drag, is bound up fundamentally with lift. Induced drag can be reduced by using wings of high aspect ratio (the ratio of the span to the chord), but the choice of aspect ratio in design is mainly determined by other reasons.

Profile drag arises from the normal pressures on the surface of a body and the skin friction which occurs in the boundary layer. Ideally, if the flow within that thin layer were laminar over the whole of the surface we should be down to rock bottom. But although great advances have been made we have not attained this ideal state.

* British Association, Belfast. Presidential Address, Section G —September 5th.

In laminar flow every particle of air moves tangentially to the surface of the body, and this is not difficult to achieve when the air is first encountered. But in its passage over the wing the boundary layer becomes thicker, and, normally, a transition point is reached when the character of the air flow changes to that of a small-scale turbulence, involving a correspondingly large increase in drag.

A considerable aerodynamic effort in recent years has been devoted in several countries to achieving as large a percentage of laminar flow as possible, and wing sections have been designed and constructed capable of maintaining laminar flow over 60 per cent of the chord. The design data in this country have come largely from the brilliant mathematics of Goldstein and the construction from the high-class engineering of the aircraft industry. The conditions required are twofold. First, the pressure conditions along the wing must be favourable—that is, the pressure must fall steadily ; and secondly, the surface of the wing must be very smooth and free from waviness. This condition is very exacting, as the surface smoothness must be equivalent to that of writing paper, and any waviness of the surface must be restricted to one or two-thousandths of an inch, in 2in measured in the direction of the chord. Rather more waviness can be tolerated in the direction along the span. Engineering difficulties in producing so true a wing surface and maintaining it in service are obvious enough.

It is possible to control the boundary layer and delay the onset of turbulence by sucking part of the layer away through slots or a porous surface. Much effort has been given to the solution of this problem both in the U.S.A. and in this country, particularly by Griffith. Sufficient experimental work has been done to show the possibility, by wing suction, of moving the point of transition from laminar to turbulent flow back to about 75 per cent of the chord, and if this principle were applied to the best modern design practice

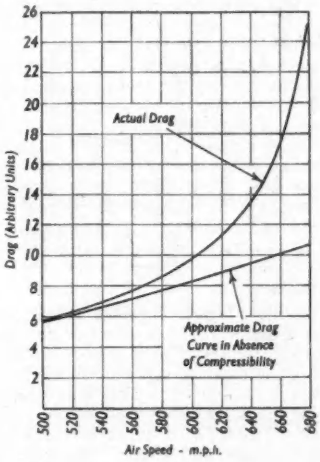


Fig. 1

we might, at a conservative estimate, expect to reduce the total aircraft drag by about 25 per cent. This is a big factor which, translated in terms of range, would give a gain of 10–15 per cent for the same take-off weight.

The real obstacle to taking advantage of these scientific and engineering advances arises from the liability of the wing to pick up at low altitudes dust particles and insects which are frequently sufficiently large to cause local breakdown of the laminar flow to the turbulent form. A possible method of minimising this kind of breakdown is to withdraw the turbulent boundary layer through a slot and thus to re-establish laminar flow downstream.

Implicit in the theory underlying the achievement of low drag is the conception of air as an incompressible fluid and, for bodies moving at speeds below and not comparable with the speed of sound, this conception is substantially true in practice. The velocity of sound in air at sea level is about 760 m.p.h. and the effect of the compressibility begins to make itself sensibly

felt above about 500 m.p.h. One effect of compressibility is to produce an increased drag rapidly increasing with rising speed and reaching near the speed of sound a value very much greater than would be encountered under conditions of incompressible flow. Fig. 1 derived from data obtained by diving a " Spitfire " from high altitudes illustrates this.

This is fundamental, for it is impossible to avoid the formation of shock waves which are the source of the largely increased drag, whenever the velocity of the air relative to the surface appreciably exceeds the local speed of sound. This is bound to happen at a forward speed appreciably below the speed of sound in the atmosphere, because the air is accelerated in its flow over a curved body such as a wing. The shock wave occurs at the downstream end of the local region of supersonic flow, and behind it the speed is subsonic. The position of the shock wave depends on the shape of the wing section and its incidence, as well as on the forward speed. When the shock wave moves back, the low pressure, in the region of supersonic flow ahead of it, extends over a larger fraction of the aerofoil surface, and there is therefore a movement of the centre of pressure with speed and incidence. This causes a considerable change in the stability of the aircraft. The presence of the shock wave may also cause a control surface located at the rear of the aerofoil to become ineffective. At supersonic forward speeds a bow wave is formed,

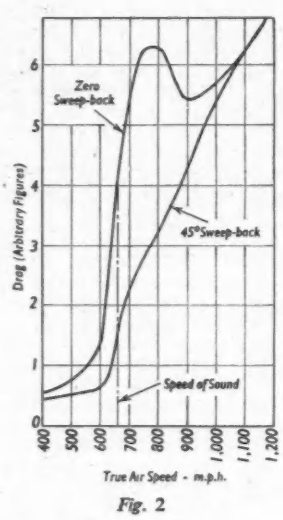


Fig. 2

and the flow again becomes stable with no serious changes in the position of the centre of pressure as the speed or incidence are varied.

It is clear that the onset of shock-wave conditions at high subsonic speeds can be delayed by reducing the acceleration produced by curvature, and high-speed flight therefore calls for thin wings and slim nacelles and bodies. These increase the critical speed, which can be raised still further by the use of swept-back wings, the effect of which is to reduce the effective thickness-to-chord ratio of the wing in the direction of flight. This great advance in aerodynamic design was first made in Germany, and its effect in delaying the rise of drag is illustrated in Fig. 2 (derived from figures given by Sir Harry Garner in his Wilbur Wright Lecture 1952), which compares the drag curves of two hypothetical modern aeroplanes of equal wing areas—one square winged and the other swept back 45 deg. The diagram illustrates also that the advantage of sweep back disappears at high Mach numbers.

The drag to be overcome at transonic speeds can therefore be considerably reduced by slimming and sweep back, and may be further reduced by more knowledge of the behaviour and control of the boundary layer immediately behind the shock waves, perhaps by suction, to prevent turbulence and breakaway of the flow. The speed of sound was thought at one time to constitute an impassable barrier, partly because of the excessive drag to be overcome and partly because of the instability and loss of control likely to arise from the changing flow conditions. Both were, of course, very real difficulties, but in the event both have turned out to be less formidable than anticipated. Much of the information which led to surmounting these obstacles came from rocket-propelled models and mainly from those experimented on by the National Advisory Committee on Aeronautics in the U.S.A. Experimental aeroplanes, both in the U.S.A. and in this country, have exceeded the speed of sound.

The air resistance at these high speeds is, however, formidable enough, and the thrust to overcome it has only become possible by the introduction of the gas turbine and propulsion by reaction from a very high-speed jet of gas.

The change from the fabric-covered biplane to the superbly finished metal-covered monoplane is due primarily to the extraordinary advances made in the properties of light alloys and methods of fabrication. When the Wright Brothers flew, aluminium was little more than a scientific curiosity, a low density weak metal of about 5 tons per square inch tensile strength. Modern aircraft aluminium alloys have a tensile strength as high as 40 tons per square inch with a density one-third that of steel, and the proof stresses of aluminium alloys have been almost doubled since the time of the first world war—an outstanding achievement providing a striking example of progress made under the spur of necessity.

The development of light alloys which could be rolled into sheet of high strength coincided with important advances in structural science and led to the introduction of the cantilever monoplane, which created a major revolution in aircraft engineering. The main structural change was the introduction of stressed skin or monocoque construction. This innovation killed two birds with one stone. It replaced fabric with a more robust material, more capable of resisting deformation and change of aerodynamic shape, and it enabled the surface covering to contribute very substantially to the strength of the structure as a whole. It made the most efficient use of material by placing it as near as possible to the outside surface. The skin now provides nearly all the torsional stiffness, whilst it also contributes to the bending strength of the wing, thus enabling a reduction in the weight of the main spars to be made. The tail surfaces have developed on similar lines, while the fuselage early lent itself to monocoque construction.

The recently developed magnesium alloys, especially those containing zinc and zirconium, have proved of great value in lightweight castings, such as those for the compressor casings of aircraft gas turbines, for they have a strength/weight ratio nearly 20 per cent greater than that of the best aluminium alloys. Magnesium alloys are also becoming available as forgings, extrusions, and rolled sheet with very promising engineering properties. High specific strength is not

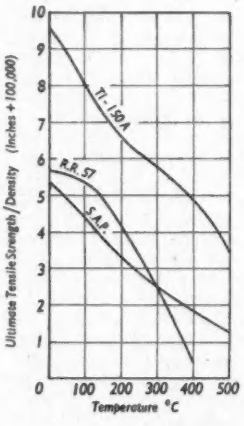


Fig. 3

their only virtue : they can be machined faster and more easily than any other engineering material, and they have completely displaced aluminium alloys in aircraft wheels. Magnesium alloys now account for about one-third of all light alloy castings supplied to the aircraft and engine industries, and the proportion is growing.

Light alloys based on aluminium and magnesium suffer, however, a rapid loss of strength with rise of temperature. This has for long been a serious drawback in reciprocating engines, where the piston temperature has limited cylinder diameter and power output. In the gas turbine, compression raises the temperature of air leaving a compressor (with a compression ratio of 6: 1) to well over 200 deg. Cent., and copper-bearing aluminium alloy blades are now giving way to those of titanium alloys containing chromium and iron, whose strength characteristics with temperature, compared with those of aluminium alloys and sintered aluminium powder, are shown in Figs. 3 and 4. Titanium alloys which have so far been investigated are twice as strong as aluminium alloys for one and a half times the weight, and further improvements in strength/weight ratio may be achieved. The possibilities ahead in the wider use of titanium alloys, both structurally and for particular use at elevated temperatures, may be great, and justifies a considerable research effort. The cost is at present high—about £5 per pound, as compared with 3s. per pound of aircraft aluminium alloys, but the commercial production of titanium is a recent innovation. The great fall in the price of aluminium from £3 5s. per pound in 1884 to 1s. per pound in 1935 was achieved by the development of new extraction techniques, and it may well be that corresponding advances will be made with titanium. However, the very reactive nature of titanium at the high temperatures which are necessary for its extraction and working present difficult technological problems, but a very great effort will,

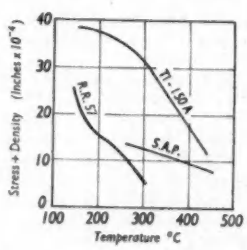


Fig. 4

without doubt, be devoted to the development of a new metal whose ores are so plentiful and which has such outstanding properties.

The ratio of the elastic modulus to density for present-day titanium alloys is, however, 10 per cent lower than the corresponding figure for steel and aluminium alloys, and this relative deficiency may, if it persists, prevent full advantage being taken of the high specific strength of titanium in aircraft structures. The development of the modern aeroplane, particularly as regards speed, has introduced a new criterion in design, namely, structural stiffness, which is now a consideration comparable in importance with strength. A reasonable degree of stiffness is essential on practical engineering grounds, but the main concern is with flutter. This is a complicated aeroelastic phenomenon in which, at a particular speed, dependent on the characteristics of the structure, oscillations occur of progressively increasing amplitude, rapidly ending in structural disintegration. Flutter is the skeleton in the cupboard of all high-speed aircraft designers, for all structures are liable to flutter in a wind in certain circumstances, and the higher the speed the greater the risk. The best a designer can do is to ensure, as far as he can, that the flutter speed is well above the highest practical flying speed.

The design criteria for achieving this are derived primarily from a masterly mathematical analysis by Frazer and Duncan in 1928, working at the time in the National Physical Laboratory. The mass balancing of the wing about its axis of twist, the close aerodynamic balancing of the control surfaces, the addition of weights to bring their centres of gravity close to the hinge lines, and mechanical irreversibility of the control system—all these measures raise the flutter speed.

But increased stiffness, both in flexure and torsion, is the principal safeguard as regards the structure itself, and this is the main reason why, as speeds get higher, the need for structural materials of higher ratio of modulus of elasticity to density becomes greater.

The stringent requirements of aircraft engineering and the striking advances made in the structural field have had their influence on other branches of engineering. Flutter is a case in point. Suspension bridges of very long span may also be liable to flutter at comparatively low wind speeds. The Tacoma suspension bridge in U.S.A. was destroyed in this way in November, 1940 in a 40 miles an hour wind. This particular problem arose recently in the design of a proposed suspension bridge of 3240ft centre span to cross the Severn estuary, and has been successfully dealt with, using accurately scaled models of dynamic similarity to full scale in a specially constructed wind tunnel.

In addition to strength and stiffness at the minimum cost in weight, a third criterion—fatigue—has to be taken seriously into account by the designer in his choice of materials, and this is becoming more and more a matter for anxiety as new alloys of higher tensile strength come into use. Aircraft encounter gusts in the atmosphere and the resultant accelerations impose loads on the structure which may be several times the normal figure. We do not know enough, either about the fundamental nature of fatigue or about the frequency and intensity of atmospheric gusts to enable this problem to be treated on an exact basis.

To fill in our knowledge about gusts, many aircraft now carry an accelerometer called "the counting accelerometer," which virtually counts the gusts encountered in flight and grades them according to severity. In the structural laboratory complete wings are subjected to a fluctuating load, broadly representative of flight in bumpy weather, until failure occurs. In addition, joints which are usually the more critical parts of a structure are tested separately in fatigue testing machines. The correlation of the flight records and the test evidence calls for judgment and experience. There is no exact answer and in these circumstances there is often room for disagreement between the scientist and the aircraft operator on the allowable flying life for an aircraft or the critical parts of its structure. Nevil Shute's novel *No Highway* is not all fiction.

I have done little more than indicate some of the scientific and engineering problems that have been encountered in the development of aircraft, and some of the ways in which these problems have been dealt with. As a consequence of these advances in the several fields of science, technology and design, and with a recognition of the vital part played by the skill of pilots, aircraft speeds have increased steadily with the years and, at an increasing rate, from a maximum speed of 70 m.p.h. in 1910 to over 600 m.p.h. in 1950. High speed, however, carries certain consequences. High flying speeds involve high rates of fuel consumption, and if we wish to travel fast we have to make it worth while in terms of a reasonable pay load and range. We can get anywhere in the habitable world in hops of about 2000 miles or so, and as we pay for speed by fuel consumption a fast aircraft at the beginning of a 2000-mile flight is virtually a flying tanker. The all-up weight of the "Comet" fully laden is about 47 tons, of which 46 per cent is fuel. Further, higher flying speeds involve higher landing and take-off speeds, and fast long-range aircraft are not only inevitably heavy, but demand long and expensive runways. Aircraft weight determines the thickness of concrete for a given sub-grade, and take-off speed, for a given acceleration, the length of runway. At the London Airport the longest runway is 3200 yards, and concrete 12in thick is used on a stable gravel base. It is estimated that the total concrete mixed to date for all purposes, including runways, taxi tracks, aprons, road diversions, ducts and drains, is about 2 million cubic yards, which is sufficient to build the concrete carriageways of a 20ft wide, 8in thick, double-track motor road from London to Edinburgh. The airport covers nearly 3000 acres and its cost to date is £10 million. Its estimated cost on completion is of the order of £20 million. If aircraft are to become faster and heavier the main economic problems in aeronautics are, in my view, less in the air than on the ground.

These very heavy runways have led to two interesting developments for decreasing the thickness of construction. The first involves the use of prestressed concrete—a modern technique which has been boldly exploited in many interesting structures. Its application to runways was first tried in 1947 at Orly by the eminent French engineer, Freyssinet. This experimental stretch of runway is 60m wide and 420m long and is built up of precast plain concrete slabs, 1m square and 16cm thick. Steel wires are threaded through the blocks, transversely to the line of the runway, at 1m intervals. These wires are heavily tensioned and anchored to either side of the runway, and so induce transverse compressive stress in the concrete.

The runway is portioned up into large right-angled isosceles triangles, and the diagonal joints thus made are closely packed with steel rollers, 20mm in diameter, inserted vertically between adjacent edges to form linear roller bearings. Longitudinal movement is prevented by deep abutments, one at each end, reaching down some 20ft or more into the ground. The effect of this is to impose a longitudinal compressive stress of similar magnitude to the transverse stress. The result is a uniform compression of the runway in all directions.

The use of precast slabs, of deep abutments and of equal prestress in all directions, is a costly procedure and experience in England with prestressed roads suggests that considerable economies are possible. A length of prestressed concrete road laid at Crawley by the Development Corporation in 1950, in co-operation with the Road Research Laboratory, uses Freyssinet cables inclined to the centre line to give designed prestressing commensurate with the different transverse and longitudinal requirements. This method avoids the use of precast slabs and of abutments and its cost was similar to that of an orthodox design of reinforced concrete road of twice the thickness.

The second development was suggested by Williams, of the Royal Aircraft Establishment, who proposed to lay concrete slabs on water bags. These bags under the runway, like the inner tubes of motor-car tyres, need only be flexible and impervious ; in neither case are the walls of the inner container required to resist any significant stress. The effect of the arrangement is to convert a concentrated load on the surface of the runway into a uniform pressure on the soil of only 2 lb to 5 lb per square inch (depending on the magnitude of the load), a pressure within the bearing capacity of all but the poorest soils. There are many practical difficulties to be overcome in working out a scheme such as this and it is not at all certain that it would be economical. However, on poor soil it may well be a possible method of construction, and experimental work is now proceeding to explore these possibilities more fully.

The flying boat offers a possible means of escape from large concrete runways and airports. Until comparatively recently the performance of the flying boat was inferior to that of the corresponding land aeroplane, but several advances have now made it a serious competitor. The flying boat always had the advantage of being able to dispense with an undercarriage, which in a modern large aeroplane may account for 6 per cent of the total structure weight, but this was for a long time more than offset by the excessive size and weight of a hull which had to carry the propellers high above the water to keep them clear of the spray. Jet propulsion has changed all this and a smaller hull, combined with improvements which can now be made in its aerodynamic design, may well tip the balance in favour of a flying boat for all-up weights of 50 tons and above. We are a maritime Commonwealth and suitable waterways for the operation of flying boats could be found in almost all the Commonwealth countries. Flying boats, however, require prepared waterways, and for boats of the size of the "Princess" and "Duchess," docking and dry-docking facilities. In the absence of detailed studies it is not possible to come to any firm conclusion about costs, but many believe that the cost of such a base would be very much less than that of a modern aerodrome, and the advantage of not depriving agriculture of much good land should not be overlooked.

A more radical and indeed revolutionary attack on the runway problem has been proposed by Green and Thomlinson, and worked out in considerable detail at the Royal Aircraft Establishment. The modern concrete runway is an expensive nuisance, however it is constructed, and the heavy and elaborate mechanism of the aircraft undercarriage an unnecessary extravagance in weight and an undesirable handicap in structural design. Green and Thomlinson aimed to get rid of both by catapulting aircraft into the air and "belly landing" them on a tautly suspended flexible sheet. For landing, the aeroplane is flown level a few feet from the ground, caught on a hook by arrester gear and dropped on the sheet, which allows a good landing without bounce to be made.

Some structural reinforcement is required for the fuselage, but this is not expensive in weight, and turns out to be small in comparison with that of the undercarriage. Launching by catapult and the use of arrester gear follows standard aircraft carrier practice, but the idea of placing on the ground, instead of in the aircraft, the means of absorbing the vertical kinetic energy on landing, is entirely new. Much experimental effort has been devoted to developing this idea and that it is quite feasible is shown by the fact that many landings of a "Vampire" have been made successfully by this method.

The ability to land on and take off from a small space may become one of the urgent problems of the next twenty years. The helicopter can do this already and that it can do so is the main justification for its existence. From its small operating bases it can travel direct from the heart of city to city. It is not capable of high speeds, as aircraft speeds go, but the Bristol 173 helicopter, which flew for the first time earlier in the year, has been designed to cruise at 120 m.p.h., and this is quite sufficient to give it an advantage in door-to-door times for journeys such as between London and Paris. British European Airways' previous helicopter services in the U.K. and the coming service between London and Paris are no doubt the beginnings of a more general use of helicopters. But the helicopter may be cast for a more striking role. It is at present a very complicated and expensive mechanism, but it could be very much simplified by jet propulsion of the rotor, burning fuel with compressed air at the blade tips. This would involve a higher fuel consumption than at present, but apart from the elimination of the need to balance the rotor torque reaction, the gain in weight saving, simplification and manufacturing costs should be very considerable. A helicopter on these lines has already flown in the U.S.A.

With folded rotor wings, as an ingenious German demonstrated before the war, a helicopter could be driven on the road from a private garage like a car to a suitable take-off point. If man is to take to the air in aircraft as he took to the road in motor-cars, this may well be the way he will do it, and long before this century is out a Henry Ford may have mass produced the first of the rotary wing motor-cars.

I confess that these thoughts may have arisen from an uneasy feeling I have that aircraft, the most mobile of all forms of transport, are in some danger of surrendering much of their mobility by becoming tied to expensive and extensive aerodromes. The helicopter, courageously pioneered by Sikorsky in the U.S.A., was for long rather like an unwanted child in the aeronautical family expensively brought up on speed. But this child which has learnt how to operate from a confined space has yet to grow up. We may see, in the not very distant future, the application of folded and faired-in powered rotors to fixed-wing machines, for use only during take-off and landing, without prejudice to top speed ; and perhaps, by removing the restraining influence of landing speed on top speed, actually make higher top speeds possible. But if this comes about, the primary advantage will lie, not in the realm of speed, but in the realisation of safer and far more economic landing and take-off conditions. The future in the air may well lie in the conquest of the ground.

THE ENGINEER

Vol. 194 SEPTEMBER 12, 1952 No. 5042

LEADING ARTICLES—
Fuel and Power Policy ... 352
Machine Tool Exhibition ... 352

ARTICLES—
Anglo-American Council on Productivity ... 360
Ash and Clinker in Industry ... 337
British Association. No. I ... 357
British Waterworks Association ... 337
Colonial Civil Aviation Conference ... 337
"Cosmotron" at Brookhaven National Laboratory. (Illus.) ... 347
Dry Docks Construction ... 337
Electrostatic Spray Painting of Tennis Racket Frames ... 360
Engine Lubricating Oil Filter. (Illus.) ... 360
Europe's Coal Problems ... 337
Foil Strain Gauge ... 348
High Altitude Research. No. I. (Illus.) ... 338
Installation of a 22MeV Betatron ... 340
International Astronautical Congress at Stuttgart ... 347
Michigan State Ferry "Vacationland." (Illus.) 361
National Policy for the Use of Fuel and Power 346
Oil Refineries near Bombay ... 364
Plastic Collapse Loads for Plane Frames. No. II. (Illus.) ... 363
Progress in Aeronautical Science and Engineering. (Illus.) ... 349
Progress at Coryton Refinery ... 337
S.B.A.C. Flying Display and Static Exhibition. No. II. (Illus.) ... 355
Strain Rosette Analysis. (Illus.) ... 341
Works of the Stirlingshire and Falkirk Water Board ... 348
15MW Gas Turbine Alternator Set at Trafford Power Station. (Illus.) ... 343

LETTERS TO THE EDITOR—
Future Demand for Coal ... 353
Locomotive Wheels and Acceleration ... 353
Aircraft Speeds at Low Altitudes ... 353

LITERATURE—
Books Received ... 353

NEWS AND NOTES—
British Patent Specifications. (Illus.) ... 367
British Standards Institution ... 368
Catalogues ... 366
Forthcoming Engagements ... 368
Industrial and Labour Notes ... 365
Launches and Trial Trips ... 368
Notes and Memoranda ... 366
Personal and Business ... 366
Technical Reports ... 356

INTERNATIONAL MACHINE TOOL EXHIBITION AT OLYMPIA —SIXTEEN-PAGE SUPPLEMENT AND FOUR ART PLATES

A FUEL AND POWER POLICY

The difficulties that faced the "Ridley" committee—whose report to the Minister of Fuel and Power is summarised briefly on page 346 of this issue—certainly began with the interpretation of the terms of reference. For the committee was asked to advise the Minister of Fuel and Power on possible measures to promote the best use of the country's fuel and power resources. In interpreting the phrase "the best use" the committee decided that the general aims of a policy on fuel and power should be: first, to meet in full the demands of the community for the various fuel and power services, when sold at prices corresponding to the relevant costs of production and distribution; secondly, to provide for the export of fuels with the most gain for the country; thirdly, to promote the highest economic efficiency in each use of each fuel, and, fourthly, to encourage for each service the fuel that gives the best returns on the resources consumed. All these aims are based on the sound premise that the efficient use of fuel will be essential, for the next few years, as a means of mitigating the anticipated shortage of fuel and power, and that it will remain important, in the longer run, as a means of conserving the country's resources.

It is clear from a study of the aims enumerated above that a national fuel and power policy must be dominated by considerations of costs and prices, and it is logical that the first commodity to be scrutinised should be coal, which is still Britain's main fuel. Unfortunately, the committee's analysis of a price structure for coal reveals a balanced cleavage of opinion. Half the members believe that the price of coal should continue to be based on the average cost of production; the remainder feel that the price should be raised, to cover the marginal cost of production, by imposing an excise duty of £1 a ton. We need not be concerned, for the present, with the niceties of the arguments which are elaborated, on both sides, in the report. We are bound to feel, however, that any such flat rate levy on the price of coal is a crude and unacceptable way of discouraging the excessive use of coal. It is particularly clumsy in that it will fall more heavily on the efficient user who has already eliminated waste than on the consumer whose profligacy leaves him a good margin for repentance. Moreover, it prejudices any attempt to devise a price structure based on the quality of the fuel. However, on the equally controversial issues involved in the domestic uses of fuel and power, the committee's verdict is unanimous. After considering the conflicting claims of solid fuel, gas and electricity, the committee has decided (wisely, we think) that "the choice should be left as far as possible to the individual consumer, guided by the relative prices he has to pay for the different fuels—provided that these prices closely correspond to the relevant costs of supplying the different fuels." This proviso, however, leads the committee to observe that existing domestic tariffs do not differentiate between charges for service during peak hours, when it is expensive in real terms, and at off-peak times, when it is cheap in real terms because the capital costs are then low. Accordingly, the setting up of a Tariffs Advisory Committee is recommended, to consider, *inter alia*, whether electricity prices correspond closely with the appropriate costs. Among the other constructive proposals made in the report are that the level of thermal insulation in houses should be raised, and that the efficiency with which solid domestic fuel is used should be increased by encouraging the production of a new design of cheap and efficient fire. By the same token one may welcome the suggestion that the 33⅓ per cent purchase tax on fluorescent lamps should be abolished, on the ground that, for a given light output they consume less current than do filament lamps. On the industrial side, consumers of fuel use the equivalent of 100 tons of coal per annum, and the committee believes that, if the right incentives are offered, the consumption of solid fuel may be reduced by 15 to 20 per cent. As a financial incentive to fuel efficiency it is suggested that the Government might well extend its recent experiment of offering loans to assist firms to install back-pressure generating sets, air preheaters, waste heat boilers and the like—with the added inducement of low interest rates and extended repayment periods and depreciation allowances. No less important in the committee's opinion is the need for an expanded service to advise industry on fuel efficiency, using the existing organisation provided by the Ministry of Fuel and Power, augmented, perhaps, by an independent advisory body formed from within the industry itself, and financed, possibly, by a levy on industrial coal.

Perhaps the most difficult of the committee's tasks has been that concerning co-operation between the fuel and power industries. Having accepted the principle of freedom of choice for the consumer and, therefore, the maintenance of competition between the rival industries, it is not easy to ensure that they will be encouraged to co-operate wholeheartedly in matters affecting the national interest. The setting up of a co-ordinating body with executive power over these industries is clearly ruled out. Instead, the report recommends the establishment of an advisory organisation which would be known as the Joint Planning Board. Its function would be to examine projects suitable for joint enterprise between the fuel and power industries, and to advise the Minister accordingly. It is possible, however, that the creation of the various bodies mentioned in the report might create as many problems as they solved. The Tariffs Advisory Committee certainly would have an unenviable task: one need only recall the ill-fated "Clowes differential" which raised certain electricity charges in the winter and lowered them in the summer. The idea behind this differential was logical and the device was probably just, but it was not made apparent that justice was being done and the tariff succumbed to the public clamour. Such is the essence of the dilemma that accompanies freedom of choice.

THE MACHINE TOOL EXHIBITION

On Wednesday next there opens at Olympia in London the International Machine Tool Exhibition, the second to be held since the end of the war. Visitors will find there, collected under one roof, a very remarkable display of machine tools from many lands. Production engineers, no doubt, will visit the Exhibition bearing in mind the re-equipment of their works or their needs for particular kinds of machines to suit new products or increase output. They will find there many old friends in the shapes of machines whose design, having proved from the first fundamentally sound, shows little change since the last Exhibition four years ago. They will find, too—and many other engineers besides those who specialise in the machine tool field will also be interested by them—numerous new machines and many which have been substantially modified or improved. Nor, beguiled by the technical interest of the heavier exhibits, should visitors forget that there will be much to see and learn about tools, materials and processes and that a large amount of ancillary equipment will be on view, particularly in the galleries. This year the Exhibition has the added attraction that it will be more fully international than ever before since much equipment made in ex-enemy countries will be open to inspection for the first time since the war, together with

products from all the other principal machine tool manufacturing countries save only those behind the Iron Curtain.

Necessarily, at a time when there is a great urge to increase rates of production, a lot of attention will be given to the automatic machines on view, some of which are capable of spectacular outputs. But interesting as these machines are both in construction and performance, it is in the basic machines—lathes, drills, millers, borers, grinders, &c., with which they are made—that fundamental improvements in design are so important. It is from advances in the design of these basic machines that the real progress in the machine tool industry is best determined; and that there has been steady progress in all countries during the four years since the last exhibition was held will be very evident. Judging from the prior information which we used in preparing the special Supplement that accompanies this issue and another that will appear with our next, machine tools of practically every class show that feed and speed rates have been increased and are wider in range, whilst controls have been simplified to permit working to closer limits with speed and consistent accuracy. Particularly noticeable is the degree to which "copying" methods are being adopted on a steadily widening range of machines, and the close limits to which working with positive stops, rather than by the skill and experience of the operator, is now possible. Hydraulic, electrical and electronic controls are being used to an increasing extent, and these forms of control are now generally designed and built as a fundamental working part of the machines and not as special or separate units for occasional use. An important factor influencing the design of the modern machine tool has been the developments made in cutting tool materials—tungsten carbide in particular. To use these tools to best advantage machines are now, practically without exception, designed on rigid lines with drives of sufficient power to give the high cutting speeds and the feeds which are possible with these tools. Our Supplements will also reveal, we think, that British machine tool makers, despite their commitments under the defence programme, are keeping their designs well abreast of modern requirements and are proving capable of producing equipment equal to and better than the best made abroad.

It is arguable, of course, that this great Exhibition should never have been organised! It has been argued publicly that when the nation is striving urgently to rearm it is an unjustified diversion of effort to make machines specially for exhibition, to hold up the delivery of others in order to exhibit them, to spend so much time in the works upon the development of new machines and to expect members of staffs to be present at all times on the various stands instead of in the works. No one is going to gainsay the weight of that argument, one at least of whose supporters knows well from experience the extreme value of an adequate supply of machine tools to a nation at war. But the nation is at present only partially at war and our rearmament is intended to prevent any further extension of war. Moreover, machine tool manufacturers here are contributing very effectively to that export trade, by means of which the nation balances its accounts. They need to remember, therefore, that competition abroad is growing, as, indeed, the display of machine tools at Hanover, almost concurrent with this Exhibition in London, emphasises. Exhibitions, besides serving the purpose of encouraging oversea buyers to place orders, have an incalculably high advertising value. Moreover, where better can engineers from this country find an opportunity to discuss with makers and amongst themselves the virtues and capabilities of the varieties of machines on view and so gain quickly the knowledge by the use of which a wise decision can be made when a machine for a particular purpose needs to be ordered? How can makers more emphatically bring home to production engineers the value of improvements recently made in speeding up production or improving accuracy? And, again, is it not a virtue, rather than a vice, that the holding of an exhibition provokes machine tool makers to have ready new machines, or improvements to old ones, by a definite date? For there is surely nothing so effective in this world for ensuring that something is done quickly (or even that it is done at all!) as fixing a time for its completion. Truly, there is a diversion of effort from immediate production to the work of development. But the user ultimately reaps the benefit and, if exhibitions are held regularly, the ultimate is never far off! We hope the Machine Tool Trades Association will abide in the post-war years by the decision taken very many years ago, but honoured as much in the breach as in the observance between the wars, to hold such exhibitions as that opening next Wednesday, every four years.

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

THE FUTURE DEMAND FOR COAL

SIR,—Mr. Peacock, in his letter of August 29th, mentions juggling with costs. I would reply that no amount of juggling with words will get away from the following facts:—

(1) That with the present average generating efficiency electricity for domestic space heating competes in fuel economy with any other method, including coke, for periods up to six hours;

(2) That the quality of fuel used for the production of gas and coke is higher, making it more valuable for export than that used to generate electricity;

(3) That in making comparisons like should be compared with like.

I am still no wiser as to the extent of the back-pressure plant in Great Britain, nor can I judge the proportion it bears to the plant installed at the B.E.A. generating stations, but I am glad to hear that Mr. Peacock's experience with this type of plant has been so successful.

R. E. GAMLEN

Brighton, September 3rd.

LOCOMOTIVE WHEELS AND ACCELERATION

SIR,—In commenting on my letter of August 23rd, your reviewer overlooks the fact that I actually included all the provisos which he stipulates—and rightly so—should be observed in statements concerning wheel diameters and acceleration. I wrote: "... all other factors being unchanged," meaning, of course, that if only the wheel diameter is changed in the tractive effort formula, a reduction in the diameter will lead to an increase in the nominal tractive effort.

Since any drawbar pull in excess of the resistance to be overcome in moving a train is available for acceleration, the higher the nominal tractive effort the greater the rate of acceleration, given freedom from slip. The product of adhesion weight per axle and the coefficient of friction is independent of wheel diameter, so that if it was practicable to take a locomotive and replace the existing driving wheels with a set of wheels of smaller diameter the rate of acceleration would be increased. The effect would be precisely that of engaging a lower gear in an automobile—and can it be denied that a car accelerates more rapidly the lower the gear? In passing, I may say that the term "ratio" should have been deleted from my letter, which should have read: "... the smaller the wheel the lower the gear."

It is agreed that the specific comparison given in my letter was worthless as a demonstration. It was cited as being of interest because it is observed so frequently with a variety of drivers in charge.

E. B. PARKER

Wirral, September 8th.

AIRCRAFT SPEEDS AT LOW ALTITUDES

SIR,—Your leading article on the S.B.A.C. display, followed so soon after by the tragedy at Farnborough, gives point to a question which has always puzzled me. Why are speeds higher than the rate of propagation of stress in air (the speed of sound) attempted at low altitudes where, due to the density of the air, such speeds will always require disproportionately great horsepower and are unlikely ever to be an economic proposition?

Surely the correct altitude for such speeds is that at which the air density, and therefore resistance, are so reduced as to minimise power requirements and stresses on the aircraft, and at the same time require really high speeds to gather enough air under the lifting surfaces for support.

The S.B.A.C. display must always be an exception, as spectators could not see an aircraft 10 miles up, but an understanding between aircraft operators that speeds above the rate of propagation of stress in air would not normally be used below a certain altitude might not only preserve the very valuable lives of test pilots, but also be a step towards reduction of the aircraft noise level which bids fair to become one of the real problems of our age.

R. E. MORRISON, M.I.Mech.E.

Walton-on-Thames,
September 9th.

BOOKS RECEIVED

Performance of Lubricating Oils. By H. H. Zuidema, London: Chapman and Hall, Ltd., 37, Essex Street. W.C.2. Price 40s.

Modern Marine Engineering. By D. W. Rudorff. London: Temple Press, Ltd., Bowling Green Lane, E.C.1. Price 9s. 6d.

Design Policy in Industry. London: The Council of Industrial Design, Tilbury House, Petty France, S.W.1. Price 3s. 6d.

Dimensional Analysis. By H. E. Huntley. London: Macdonald and Co. (Publishers), Ltd., 16, Maddox Street, W.1. Price 20s.

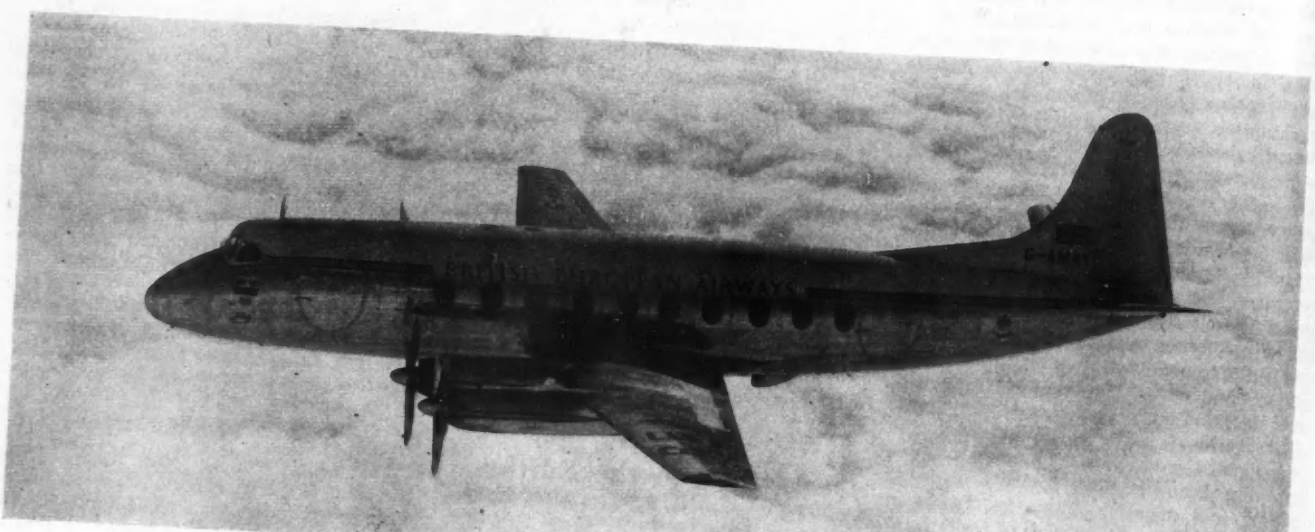
Modern Lighting Technique. By Harry Hewitt. London: Edward Arnold and Co., 41, Maddox Street, W.1. Price 21s.

Nomography and Empirical Equations. By L. H. Johnson. London: Chapman and Hall, Ltd., 37, Essex Street, W.C.2. Price 30s.

The Electrical Engineers' Reference Book. Sixth Edition. Edited by E. Molloy. London: George Newnes, Ltd., Tower House, Southampton Street, Strand, W.C.2. Price 63s.

An Explaining and Pronouncing Dictionary of Scientific and Technical Words. By W. E. Flood and M. West. London: Longmans, Green and Co., Ltd., 6–7, Clifford Street, W.1. Price 12s. 6d.

The Bristol "Britannia" Airliner



The Vickers "Viscount" Airliner

The de Havilland "Comet" Airliner

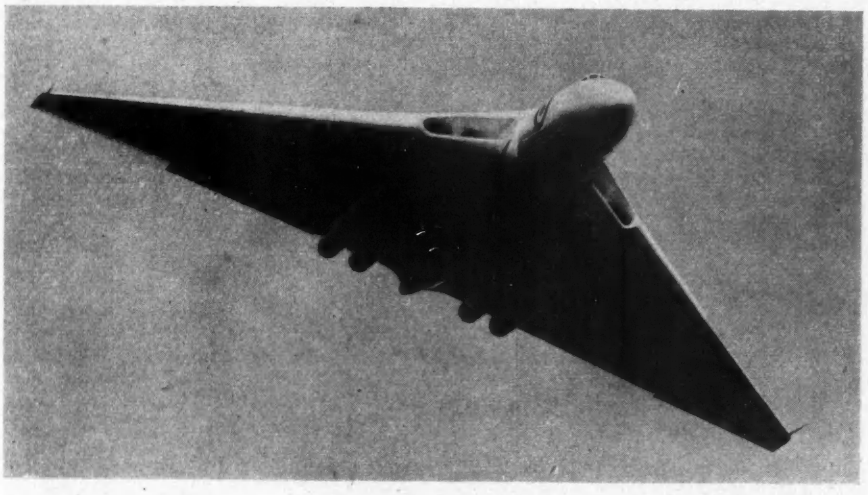
The S.B.A.C. Flying Display and Static Exhibition

No. II—(*Continued from page 326, September 5th*)

TOWARDS the close of the second public day, Saturday, September 6th, at the S.B.A.C. air display, the first prototype "DH110" disintegrated at a low altitude over the precincts of the aerodrome after making a high-speed, low-level demonstration run. Both engines left the airframe; one of them fell into a section of the crowd, and some of the larger sections of the airframe struck the runway and other public enclosures. The pilot, John Derry, his observer, Tony Richards, and 28 spectators were killed and 62 injured. After a short period the flying programme was resumed on that day and on the final day, Sunday, September 7th.

The pattern followed during this fatal demonstration had not appeared to differ materially from that used earlier in the week, both by the "DH110" and the Hawker "Hunter," flown by Neville Duke. Following a steep dive seemingly aimed at the airport from about 40,000ft, these machines achieved Mach numbers slightly greater than 1, and then swept down the demonstration runway at heights of about 20ft and at speeds unofficially estimated at between 680 and 720 m.p.h. Invariably their passing of the enclosures was preceded by a few seconds by an aural phenomena consisting of two distinct reports in rapid succession similar in many respects to the sound of thunder characteristic of a very local and severe storm. It was also customary when at the end of the run to illustrate the manœuvrability of these aircraft at such speeds by climbing vertically and executing a series of vertical rolls.

Before turning to aircraft serving less military functions, further mention might be made of the Avro "698" four-jet delta bomber. It appeared in the sky each day accompanied by the two Avro research delta machines, and only by the aid of these apparently geometrically similar models was it possible to appreciate the huge size of this seemingly flat triangular shape. It was, indeed, a momentous occasion when this arresting profile first circled the perimeter of Farnborough airport. One suspected that the pilot was himself wary of its nature before he gradually reduced the height at which he was circling and then finally and confidently maintained a moderately steep turn within the perimeter at a speed probably in the region of 100 m.p.h. There could be no sterner way of proving the handling characteristics of an aircraft, new in so many respects, without slots, without flaps and without tailplanes, than such a manœuvre when only on its fourth flight and within a few feet of the ground.



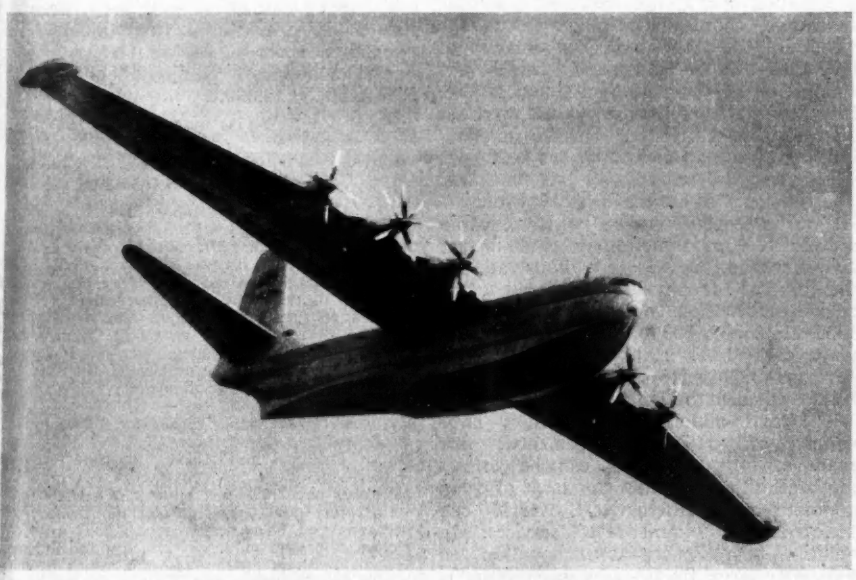
The Avro "698" Delta Bomber

Civil and Freight Aircraft

Such has been the success attending the progress of this country's gas turbine civil airline projects that the issue had ceased to be one of proving and developing; it had become one of producing.

For there has been increasing evidence recently that a world-wide demand has been created for both prop-jet and turbo-jet propelled aircraft which, in view of our other commitments, will swamp production capacity. Should this situation develop the lead which this country rightly enjoys in this completely new field would very soon be frittered away.

This year there were three civil aircraft fitted with gas turbines which are in full production. The "Viscount 700" airliner made by Vickers-Armstrong, Ltd., was the first turbo propeller liner to be operated commercially. Its prototype "Viscount 630" was also the first propeller turbine aircraft to be granted a certificate of airworthiness. It was operated successfully on schedule passenger services over existing routes. It is a medium-sized airliner and is intended for the short-haul and medium-range routes. Development of this type has led to an increase in all-up weight from 50,000 lb to 52,500 lb, most of which has gone to increase the fuel capacity. The type "701" is now in production for B.E.A. and similar versions are for Air France and Aer Lingus. The aircraft has four Rolls-Royce "R Do 3 Dart" propeller turbine engines each developing 1400 s.h.p. plus the jet thrust of 365 lb, which drive four-bladed, constant-speed, fully feathering Rotol propellers. Much has now been said of the low noise levels associated with this kind of propulsion, which, with the absence of vibration obtaining with the purely rotary prime movers, has introduced a mode of comfort not available in any other kind of public transport. Its handling characteristics are well known and its demonstrations at Farnborough this year and previous years have usually illustrated its low landing speeds and its manœuvrability with three engines feathered. Some of its other safety characteristics include duplicated brakes on twin wheels, crash-proof fuel tanks, thermal de-icing and the use of all cabin windows as emergency exits. The cabin is pressurised to operate at a maximum differential pressure of 6½ lb per square inch, which gives 5000ft conditions at 20,000ft. The type "701" is now in full production for British European Airways, and it is expected to be in service next month. This version is able to accommodate forty or forty-eight passengers with provision for a pantry, one toilet, freight holds and a flight crew of three. The "Viscount" has a span of 94ft, length 81ft 2in, and an all-up weight of 52,500 lb, giving a wing loading of 54·5 lb



The Saunders Roe "Princess" Flying Boat

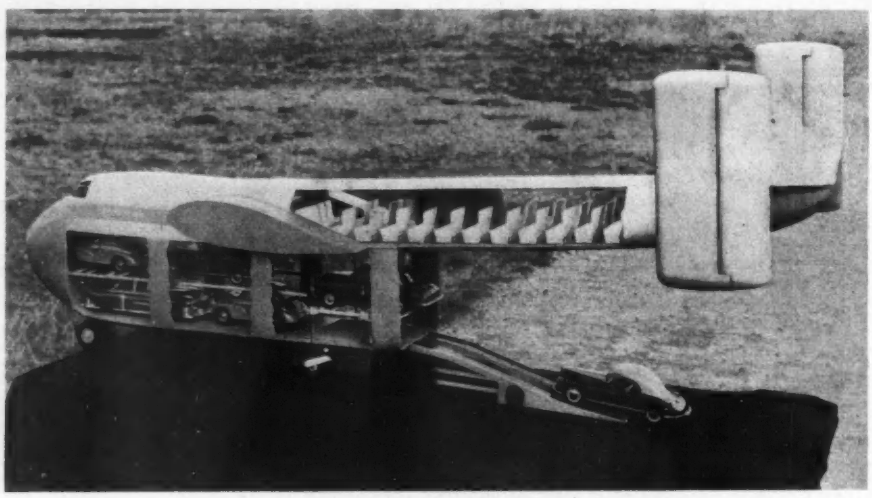
per square foot. It has a ceiling of 30,000ft and the designed cruising speed at 25,000ft is 270 knots. The cruising consumption is given as 0·135 nautical miles per pound fuel and the still air range at 25,000ft is 1900 nautical miles.

The " Comet " airliner made by the de Havilland enterprise has long been the focus of world civil aviation interests, a focus which has been sharpened in recent weeks by the forceful inquiries of leading American airlines for early deliveries.

It will be recalled that " Comet " Series I aircraft have now been operating the B.O.A.C. London–Johannesburg route since May this year, and were thus the first pure jet civil aircraft in the world to be placed in service. The first prototype

The urgency of development trials now in progress prevented the showing at Farnborough of the series 2 " Comet," with four Rolls-Royce " Avon " engines, these engines having axial-flow compression have a markedly lower specific fuel consumption than the centrifugal flow " Ghost " units. This series is thus capable of carrying forty-four passengers on the long stages of world travel, and should be in service by 1954. It is expected to be extensively employed in the years which follow.

The other outstanding British gas turbine propelled civil aircraft in large-scale production is the " Britannia " airliner made by the Bristol Aeroplane Company, Ltd. From time to time in these columns we have reported upon the development of the proto-



Model of the Blackburn Universal Freighter Mark II

" Comet " was this year used to demonstrate take-off with two " Sprite " rocket motors augmenting the thrust of its four de Havilland " Ghost " turbo-jet engines of 5000 lb thrust each. These rocket motors fit between the jet pipes of the " Ghost " engines, and they are used when the aircraft attains a forward speed of 50 m.p.h. Together, they provide an additional thrust for about twenty-six seconds of 10,000 lb with which the aircraft is able to demonstrate a much steeper initial rate of climb. Time had prevented the mounting in this aircraft for take-off demonstration purposes of " Ghost " engines equipped with water-methanol injection apparatus.

In the static park was the first of the " Comets " for Canadian Pacific Airlines scheduled for operation early in the New Year between Sydney and Auckland and Honolulu. This " Comet," a series 1*a* machine, represents the first stage in the upward development of the craft. The fuel capacity of the series 1*a* has been increased to 7000 gallons, enabling it to operate over stage lengths some 20 per cent longer than the series 1. Series 1*a* aircraft will be fitted with " Ghost " engines incorporating water-methanol injection, which has the effect of increasing the thrust by approximately 12 per cent in high-temperature conditions. In terms of " Comet " take-off performance it is equivalent to lowering the ambient temperature by about 10 deg. Cent. The all-up weight of the series 1*a* aircraft is 110,000 lb, representing an increase of 5000 lb over the series 1. It has accommodation for forty-four passengers. It has a span of 115ft, length 93ft, and a wing loading of about 54·6 lb per square foot.

type, which first flew on August 16th, and on the non-flying prototype, an almost complete aircraft upon which much flight development normally carried in the air has been simulated in advance.

The advantages which derive from propeller turbine propulsion are well illustrated by comparing the performance of this aircraft with a piston engine such as the " Brabazon." For both were designed to carry the number of passengers which would make their operation an economical proposition over routes requiring a still air range of about 5600 miles. Yet the weight of the " Britannia " is only about half that of the " Brabazon," which was claimed to be the minimum practical size. It has considerably more thrust and it cruises almost 100 m.p.h. faster. The " Britannia " is being produced on priority for B.O.A.C., which has ordered twenty-five machines. The four engines are the Bristol " Proteus " III turbo-propeller units, with which a specific fuel consumption of 0·48 lb per equivalent horsepower per hour at 350 m.p.h., 35,000ft has been achieved. The engines under these conditions each develop 1335 s.h.p. plus 300 lb residual thrust, and under sea level static conditions each develops 3320 s.h.p. plus 1200 lb thrust, being equivalent to 3780 h.p.

The seat attachment permits a large variety of seating arrangements ; for example, fifty passengers can be accommodated with the highest standards of cabin appointment, or, alternatively, over 100 can be carried on " tourist-rate " services. In addition to passenger accommodation, an unusually large freight stowage volume is provided.

The all-up weight of the aircraft is 140,000 lb, of which 25,000 lb may be payload. Its still air range with this payload is 4000 statute miles, but with a 12,000 lb payload a still air range of 5600 miles is attainable. The mean cruising speed is 360 m.p.h. Other details of the " Britannia " are as follows :—Span 140ft, length 114ft, height 36ft 8in, track 31ft, fuel capacity 6800 gallons.

One was able to appreciate the graceful but conventional lines of this machine at the display. The wing is straight with an aspect ratio of about 9 : 1. Particularly significant was the quiet hum of its engines which stamped it as the least noisy machine at the display.

Not to be denied, the huge "Princess" flying boat at last was able to join in a flying programme at Farnborough. Curiously enough, travelling at about 280 m.p.h. and with the note of its ten Bristol " Proteus " turbines belying the power developed, one had to recall the paper specification to realise that it shared the distinction with the " Brabazon " of being one of the largest aircraft ever made.

In the static park only, this year, stood a Mark I version of the " Universal Freighter," made by the Blackburn and General Aircraft, Ltd. The company has now recently received a production order from the Ministry of Supply for a Mark II version, which will have four Bristol " Centaurus 171 " double-row radial engines, each developing 2940 h.p. This aircraft is exceeded in size only by the " Princess " and " Brabazon " machines. It has a wing span of 162ft and stands 37ft 6in high. Its outstanding characteristic is the size of its freight hold, which occupies 6311 cubic feet and is able to accommodate a payload of 49,300 lb. It provides also an unobstructed floor space 40ft by 10ft with 10ft headroom. With this payload its range is 250 statute miles ; at 3000 miles the payload is 12,400 lb. The operating cost in pence per ton-mile can be as low as 9d. In spite of its size and weight it has been designed to utilise the more primitive landing areas, and to operate with field maintenance. The wing loading is 44·6 lb per square foot and it is able to clear 50ft (maximum a.u.w.) after a run of 1130 yards on grass strip ; with braking propellers and wheel brakes the distance from 50ft to rest is 720 yards.

One projected internal arrangement for prospective civil customers is illustrated herewith. It provides an internal lift to assist the loading of six normal cars, and passenger accommodation for forty-two people is provided in the boom. The maximum speed is 239 m.p.h. at 5700ft ; most economical cruising is obtained at 197 m.p.h. at 12,500ft.

(*To be continued*)

Technical Reports

The Measurement of Copper Losses in Transformers and Reactors. A Critical Review of Existing Methods (Ref. Q/T 129). By M. Waters, B.Sc., A.M.I.E.E. The British Electrical and Allied Industries Research Association. Price 12s., postage 3d.—The measurement of copper losses in transformers of small and medium sizes is relatively simple. In reactors and very large transformers however, difficulties are caused by the very low power factor. In this report the problem is discussed and the available methods are compared.

Commercial Pulverising Experience. Report Based on Replies to a Questionnaire (Ref. P/T 105). The British Electrical and Allied Industries Research Association. Price 15s., postage 4d.—A questionnaire was circulated to a number of users of pulverised fuel grinding plant, and the replies have been analysed. The present report gives a general picture of present pulverising practice and indicates several important lines of research, which is being carried out in collaboration with the British Coal Utilisation Research Association.

The British Association

No. I

Inaugural Meeting

THE first general assembly of members of the Association attending the annual meeting in Belfast was held in the Sir William Whitla Hall of the Queen's University on Wednesday, September 3rd. Because of the large number of members present—a record for any meeting held outside London—an overflow meeting, to which the proceedings were relayed, was held in the adjoining Methodist College.

The Chancellor of the University, Viscount Alanbrooke, expressed the deep appreciation of the meeting of the presence of H.R.H. The Duke of Edinburgh, the immediate Past President of the Association, and asked him to convey their respectful greetings and humble duty to Her Majesty.

The Chancellor then conferred the degree of LL.D., *honoris causa*, on Professor A. V. Hill, President of the Association, and on Dr. D. W. Bronk, President of the American Association for the Advancement of Science. In the war, he said, the scientists of the United States and of the British Commonwealth worked side by side for victory, and it was gratifying to see the same happy partnership maintained in the peaceful exploration of nature and in the pursuit of knowledge.

He also conferred the degree of D.Sc., *honoris causa*, on Professor E. D. Adrian, O.M., F.R.S., Sir William Slater, and Sir Richard Southwell, F.R.S. Professor K. G. Emeleus, in presenting Sir Richard Southwell, said that the keynote of his work, like that of Leonardo da Vinci, was its universality. He had been more successful than Leonardo, applying the theory of flight to practice ; to this end he became an intrepid balloonist, and had been largely responsible for the development of airships in this country. His genius lay in the masterly handling of mathematics, to such effect that it had changed from what engineers commonly regarded as an obstinate and capricious despot to a useful and benevolent genie, giving at command the solution of all kinds of problems. In his own words, applied physics had been freed from the systematic botany of mathematics. He had called the new technique "the systematic relaxation of constraints." "Relaxation" had a sweeter sound even than the "method of least work," and so it had proved ; involved computation had been reduced to relatively simple arithmetic. It was clear that so far only the fringe of the vast range of engineering and physical problems to which the relaxation method could be applied had yet been explored.

The Lord Mayor of Belfast (Councillor J. H. Norritt) and the Vice-Chancellor of the Queen's University (Dr. Eric Ashby), having offered a welcome to the Association, Professor A. V. Hill, C.H., F.R.S., the President, took the chair and delivered his inaugural address, entitled "The Ethical Dilemma of Science," which was reproduced in last week's issue.

H.R.H. The Duke of Edinburgh, who proposed a vote of thanks to the President for his address, read a message from the Queen conveying her good wishes to the members of the Association. "I well know," Her Majesty wrote, "that the strength of our country and Commonwealth depends more and more on the skilful application of scientific discoveries to the many problems that beset us to-day. With this in mind, I am happy to extend my patronage to the British Association, whose meetings afford scientists, old and young, such inestimable opportunities of freely exchanging their knowledge and their ideas."

Professor Hill, the Duke of Edinburgh said, had described ably and fearlessly what responsible scientists were thinking and had stated their problems clearly and courageously. In his conclusions he had demonstrated that integrity of thought which was the hallmark of all great scientists. His address would be welcomed by scientists throughout the world as sound common sense and wise counsel. To the layman he had made the issues and responsibilities clear. He had referred to the essential principles which governed scientific thought and action, and without which no progress of any value would be achieved. In the same way, the Duke of Edinburgh believed that Christian principles should govern the thoughts and actions of the community at large. The compelling duty of the good citizen was to apply those principles to all the problems of modern life.

Vibrated Concrete

At a meeting of Section G (Engineering) of the British Association on Thursday, September 4th, Mr. D. A. Stewart read a paper on "Some Recent Developments in Concrete Technology," with special reference to vibrated concrete. Principal D. H. Alexander, O.B.E., M.Sc., of the Belfast College of Technology, who occupied the chair, referred to the fact that the mechanical engineer had at his disposal a big army of highly skilled men, whereas the civil engineer, even when dealing with large structures, had to rely largely on unskilled workmen. The application of concrete to structural work might appear to be easy, but that was far from being true in practice.

Mr. D. A. Stewart, in presenting his paper, showed a film depicting the building, in vibrated gap-graded concrete, of a wind tunnel a quarter of a mile long and 50ft in diameter. The shell was doubly reinforced with ½in bars on both faces and an 8/1 mix was used, the maximum size of aggregate being 1½in and the minimum ¼in. The sand all passed a No. 14 sieve. The sand content was 28 per cent of the combined aggregates and the water/cement ratio was 0·5. The tunnel was made in 90ft sections. There had to be no shrinkage cracks, no crazing, and an absolutely perfect surface. One difficulty with gap-graded concrete was to get it out of the mixer, mixers having been designed fifty years ago for very sloppy concrete. Many of them produced very inadequate mixing, and in fact extremely good segregation, unless care was exercised. Examining the tunnel after eighteen months, he could not find a single craze mark on the inside. About 3000 tons of concrete had been used, and the method adopted saved 300 tons of cement and gave better strengths than had been asked for. Great accuracy in construction had been called for, with a tolerance of only 1½in on a diameter of 50ft.

Replying to questions arising from his paper, Mr. Stewart said that the frequency of vibration varied with the conditions in which the concrete was compacted. When the concrete was introduced into the mould the individual particles were well separated, and a relatively large amplitude was necessary to transmit the vibration to particles which were a considerable distance away, if it was desired to speed compaction. When the concrete was almost fully compacted it was obvious that in the last stage the total movement of the particles must be very small and one required a very small amplitude of vibration but a large acceleration. If there was a large acceleration at the beginning, with a large movement and high frequency, tremendous stresses would be involved, going up to 150*g*. The high frequency should be reserved for the last stage of "massage" in the place where it was wanted. The range of frequency would be from 3000 per minute to begin with, to 15,000 at the end.

Dealing with the question of compressive strength, he said that with a 7/1 mix with ¼in to ⅜in aggregate the twenty-eight-day strengths averaged 6800 lb per square inch. Strengths of 7000 lb per square inch had been obtained at seven days with a ratio of 7½/1 and 1½in aggregates. As compared with ordinary concrete, the aggregate/cement ratio could be very much reduced for equivalent strengths, because the water/cement ratio law did not apply.

Transmission Line Constants

Mr. D. A. Stewart's paper was followed by a paper by Professor R. O. Kapp on "The Calculation of Transmission Line Constants." In presenting the paper, Professor Kapp said it showed that a fuller appreciation of the physics of power transmission would lead to the presentation of formulae in forms very much easier to handle than those found in the textbooks, but they could never be simple, because of the number of parameters to be taken into consideration. There was, he added, a tendency to approach a.c. problems with a "d.c. habit of mind," due to the fact that electrical engineering in its infancy had been direct current engineering.

Professor Kapp developed simplified formulæ for the three line constants *A*, *B* and *C*, and pointed out that these formulæ could be used without tables of hyperbolic functions, since they required only the circular functions. Although a series of approximations were made in developing the formulæ the errors were not all additive. Some of the errors tended to cancel each other : the total error was therefore small, being less than 0·7 per cent for either the real or the imaginary component of any of the constants, for lines up to 600 miles long. The author stated that his approximate formulæ were likely to serve all practical purposes, since a high degree of accuracy was very rarely necessary in the calculation of transmission line constants.

The Biology of Flying

A joint meeting of Sections G (Engineering) and I (Physiology) was held on Thursday, September 4th, at which four papers on the biology of flying were presented. Dr. K. G. Bergin dealt with the medical aspect of the subject, Group Captain W. K. Stewart with physiological problems of high performance military aircraft, Dr. W. E. Hick with "Skill and the Airman," and Mr. D. G. A. Rendel, of the Royal Aircraft Establishment, with engineering problems of conditioning aircraft for human occupation and control.

Group Captain W. K. Stewart, head of the R.A.F. Institute of Aviation Medicine, said that, in applying the basic medical sciences to flying personnel, an intimate liaison was maintained with engineers both in the laboratory and in the field. Modern

military aircraft imposed stresses much greater than the powers of adaptation of the human body and in the next decade the solution of physiological problems might have to take precedence over problems of design.

Physiologists could best aid the engineer by information on the useful limits—the limits varied widely—of what the body could withstand, and particularly in connection with the response of the seated body to loads imposed by acceleration and deceleration. With a sudden acceleration upwards, 20*g*. was the limit which could be imposed on a fit young airman. When the aircraft was decelerated and the man was sitting facing forwards a limit of 25*g*. had been imposed, but the Americans had recently extended this to over 40*g*., these figures being for a period of about 10 seconds in the application of the acceleration or deceleration. If during deceleration the man faced aft there was virtually no limit, since the body was stronger than the structure of the aircraft. When a man was pulled downwards and the strain taken by the safety harness the limit was about 11*g*.

The R.A.F. had to provide oxygen equipment for the occupants even of pressurised aircraft. The ventilation volume was about 12 to 14 litres per minute for the pilot, but under conditions of excitement, fear or anoxia the rate and the volume might go up. At take-off and landing and also during aerobatics, the rate went up. The oxygen equipment provided by the engineer must be able to pass a gas flow of 200 litres per minute at a back pressure of 2in H_2O, and at 12–14 litres the back pressure should be about 0·1in. The co-operation of engineers was also necessary in the design of pressurised cabins, where, if the cabin was "holed," great changes would take place in a hundredth of a second. Without additional oxygen the crew should not be exposed to cabin altitudes greater than 8000ft, and 5000ft was preferable. Following explosive decompression at 52,000ft consciousness was lost in less than 15 seconds, and this fact constituted the most dangerous limitation to high altitude flight.

Since the integrity of the cabin could not be guaranteed, engineers must provide either a method of escape from the aircraft which could be used before unconsciousness supervened, or an artificial atmosphere round the pilot. The method of escape must involve the least possible expenditure of muscular energy, and so must take the form of an "ejection seat," automatic in action.

Another problem was the sickness which might be caused by exposure to high altitudes and low pressures. The engineer must provide a seat which, without cramping the pilot, would give the shortest distance between the ankle and the heart, and the heart and the eye. Artificial methods of protection, such as "anti-*g* suits," were necessary to give positive abdomino-thoracic pressure ratios proportional to the acceleration imposed. Cabin temperatures could vary between ±60 deg. Cent. and the relative humidity from 80 to 5 per cent. In addition, there might be abnormal pressure gradients.

Dr. W. E. Hick, of the Medical Research Council Applied Psychology Research Unit, Cambridge, said that the study of piloting skill was a special branch of the wider subject of the properties of the human operator of machine controls of all kinds. It was only in the last twelve years that engineers, physiologists and psychologists had come together to elucidate the nature of the skill involved. The problem was that of the behaviour of the man-machine combination, and especially the "optimisation" of that behaviour. Its solution was necessary to enable the designer to fit the machine to the man, and to a lesser extent to enable the man to be fitted to the machine.

The designer described the behaviour of the machine in response to the controls mathematically and, to complete his picture, needed a mathematical formulation of the relevant properties of the pilot. If one admitted "probabilistic" laws as valid partial descriptions and limited oneself to the pilot's moment-to-moment reactions, that was an attainable objective. Two mathematical techniques had been enlisted in this study: the theory of cyclic systems or servo-mechanisms, and the theory of information and communication.

The pilot could be regarded as a link in a closed loop, as a sort of computing box into which information was fed at one end and from which it was delivered, suitably (or unsuitably) transformed, at the other. The pilot's output was a set of independently-varying muscular forces applied to the various controls. The effects of these forces passed through the aircraft and its instruments and back to the pilot's sense organs. The system was complex, and was made more so by time lags in the pilot and the aircraft.

The Human Response

In general, if the human operator of a control mechanism was trying to minimise the error or deviation from some desired state, which might be varying, the effective stimulus was roughly the weighted sum of the deviation and its rate of change. The response could best be regarded as a handle-velocity, with possibly a small component of handle position. In these terms, the effect of the human reaction time was equivalent to a fixed time-lag of about 0·3 seconds. A simple model of the human operator performing a continuous controlling task of the kind in question was therefore:—

$$(A+p)H=e^{-0\cdot3p}(B+Cp)E$$

where E was the deviation, H the handle displacement, and $p=d/dt$. This was the simplest differential equation which bore a useful relation to the facts and, combined with the differential equation of the control mechanism, it would make it possible to find the stability and frequency response of the system as a whole, if the value of the constants was known. Even without them, one could discover whether any reasonable values would make the system satisfactory.

The constants, however, had no fixed values. They varied between individuals, they varied at random from moment to moment and day to day, and they varied systematically as practice adapted them to the mechanism being operated. They were, in fact, averages which were, at best, relatively constant for a limited time.

The human operator had resources not accounted for in the simple model. He could, for instance, utilise some of the past history of the deviation, such as, that it had been oscillating for the last few seconds. This occasional intervention of an over-riding influence could be of practical importance in using a mechanism which was underdamped and had a natural frequency in the region of 1 c/s. Due to the reaction time lag, there was a tendency to resonance when man and machine were linked together in a closed loop. In certain aircraft oscillatory tendencies, especially in pitch, were a natural concomitant of the highest performance and might well be near the resonant frequency. A pilot unused to this sort of idiosyncrasy could rapidly set up a violent and perhaps dangerous oscillation, but the chief significance of the phenomenon was that it forced the pilot to adopt a technique less efficient than it otherwise could be. The trick of stopping such oscillations, however, was very simple and seemed to come naturally to some people.

Even when the control was fully damped and aperiodic, the fact that the man had, by virtue of his reaction time, a natural frequency became important when considering the random errors or fluctuations ineradicable from any manual skill, for they tended to excite oscillations at this frequency. One consequence was that the man must, for optimum performance, use a lower "gain" or "gear ratio" than he would if there were no random disturbance; i.e. he must respond with smaller movements or forces. It also affected the possible performance and the optimum design of the control mechanism.

Flying controls had normally a large aerodynamic restoring force and the range of movement used in accurate control at high speeds might be almost imperceptible. With the advent of power-operated controls, any desired "feel" could in theory be provided. It had been found that with a velocity control, and possibly with others, it was best to use a lever which had no appreciable movement, but to which the operator merely applied forces.

The random element in human behaviour was even more important in connection with the ancillary controls and with instrument reading. It did not require much skill to press the button which lowered the undercarriage; the skill lay in never forgetting to press it. The art of not making such omissions and mistakes might be called "reliability skill." The whole range of a pilot's skill amounted to the correct translation of information received into action taken.

That would be a platitude but for the fact that there was now available a usable definition of "quantity of information." Information theory was concerned with "accuracy per second." It was essentially "probabilistic." For instance, the maximum amount of information per second could be transmitted through any channel, human or otherwise, when the signals were in such a form that the most probable required the least time and the least probable the most time. Psychologists had recorded inaccuracies, in the form of errors and omissions, in innumerable experiments, while measurements of the time taken to react in various ways in various conditions go back a century or more. Information theory provided, for the first time, a rational basis for combining these two types of measurement.

Mr. D. G. A. Rendel (R.A.E.) said that the most marked feature of the engineering problems concerned with flying at high speeds and high altitudes was that there was no precise or complete solution of them. The act of flying appeared to be one for which human beings were not conditioned in any way, and there seemed to be no instinctive reactions to the situations presented in flying an aircraft. Under the atmospheric conditions in which flights were made at high altitudes and speeds, life could not be sustained at all without special apparatus, and the best that could be done was to devise systems of control which required the minimum of acquired skill, and atmospheres in the cabin which enabled human beings to exist in an atmosphere similar to that found on the ground.

The success obtained had to be judged, unfortunately, on purely subjective criteria. Individuals reacted in different ways to a particular piece of apparatus or atmo-

sphere. In aircraft flying between Britain and the United States the controlled atmosphere which was provided was nearly always too cold for the American passengers and too hot for the British. In addition, there was the difficulty of providing moral confidence in the pilot, making him feel that he would be capable of dealing with any emergency which arose and, in military aircraft, that he would have a chance of escaping if all else failed.

The control of the atmosphere in an aircraft cabin differed in one major respect from air conditioning of space on the ground, because in the cabin it was necessary to provide the conditioned atmosphere at a pressure which would allow the occupants to breathe when the aircraft was at high altitude. Unless the pressure was kept up, the occupants would soon become unconscious above 30,000ft. The air must be supplied at a pressure equivalent to a comfortable altitude, in quantities sufficient to provide the necessary oxygen, and at a temperature which would ensure that the cabin was uniformly and comfortably warm when the heat flow in and out was balanced. In the latest types of civil aircraft the cabin altitude was normally kept at the equivalent of 8000ft, or about 10½ lb per square foot abs., and about 2 lb of fresh air per minute was provided for each occupant. The temperature was kept between 60 deg. and 75 deg. Fah.

The engineering problems which this presented were of considerable difficulty. The conditions were continually changing all the time with great rapidity and over a very wide range, and there was a measure of conflict between the air pressure and air flow requirements on the one hand and the temperature and heat flow requirements on the other. The conditions which existed outside had to be converted to conditions of comfort in the cabin. The effective temperature was that which gave a reasonable degree of comfort to a man in normal clothing with an air velocity of 15ft to 25ft per minute. What was regarded as comfortable in the tropics differed from what was so regarded under British conditions, and so in an aircraft travelling from Britain to a tropical zone the passengers had to be switched from one zone to another in the course of the flight.

The problems involved were well on the way to being overcome in civil aircraft, but military aircraft were more difficult to deal with. They flew at higher speeds, at which the speed itself affected the temperature of the air. At very high speeds the air was compressed in front of the aeroplane adiabatically, and as the Mach number went up the temperature rise at the maximum position, immediately in front of the intake, went up very sharply. At a Mach number of 1 there was a 40 deg. Cent. rise, which meant that, in the tropics, fairly near the ground the temperature of the air was around the boiling point of water. In addition, the pressure rise associated with Mach number was also considerable as one went up and there was a pressure ratio between the atmosphere and the pressure at the intake of 3 for a Mach number of 1·4, which represented, when flying at 60,000ft, an equivalent decrease in altitude of about 20,000ft. Near the ground, therefore, the air might be coming in at a pressure considerably greater than at atmosphere of 1, and that further complicated the design of the air conditioning equipment.

For altitudes below 25,000ft the problem was well on the way to being solved. Very little humidity control was required, the necessary heating or cooling could be provided easily and if the cabin failed it did not mean a catastrophe. Above 25,000ft the higher speed led to increased temperature and a failure of the system would probably be fatal. The solution was to provide the crew with clothing which was pressurised and ventilated. That presented difficult engineering and tailoring problems.

The next problem in relation to civil aircraft was noise and vibration. There was at present no satisfactory method of measuring objectively the discomfort caused by noise and vibration. Nor could a clear line of demarcation be drawn between the two, because structure-borne vibration could produce noise and noise could produce structure-borne vibration; the two could not be distinguished except in terms of frequency. All that could be done at present was to measure noise levels by the instruments used on the ground—a microphone and a filter which filtered the noise into different octave bands—and record the noise levels in decibels on a frequency basis. It had been found that the noise levels in turbine-engined aircraft as measured by this arrangement differed very little from the standard curve obtained with piston-engined aircraft, but people who travelled in turbine-engined aircraft were emphatic about the increased comfort from the point of view of noise. That seemed to be due to the fact that there was very much less structure-borne vibration, which could not be measured by using a microphone.

A problem which would arise in future was that of the aerodynamic noise due specifically to high-speed flight. Above the speed of sound the noise due to the passage through the air probably became of greater relative importance than all the rest of the noise put together, but so far the theoretical concepts which they had tried to develop to establish how aerodynamic noise arose were very difficult to grasp, if they could be grasped at all, and designers were faced with the need to have some relativity principle to deal with a noise source which was moving at speeds comparable with or greater than the speed of sound.

Control Problems

Then there was the problem of providing a reasonable kind of control for the aircraft. The engineer had so to design the controls that the strategic decision of the pilot could be put into effect tactically as easily and accurately as possible through a servo mechanism of which the pilot was one component. The most obvious difficulty was that the aircraft could move in three planes and could rotate in any of them and perform almost any combination of manœuvres instantaneously. There was also the problem of the lag between the control movement and its effect in the aircraft control system and on the manœuvre, which could be quite considerable. Moreover, in high-speed aircraft the pilot could, with quite small forces, by mishandling the controls easily break the aircraft up. It was essential, therefore, that he should have a warning indication (which he could not overlook) of what he was doing to the aircraft, and which would enable him to feel instinctively what he should do next.

For tactical control purposes in flight visual indications were of limited value and could be misleading. The pilot had no visual datum to which he could refer, and rates of change of position could often be assessed only instrumentally or by feel, particularly at night or in cloud. At high speeds, indication by instruments increased the time delay in the pilot's response, and the number of observations necessary to control the aircraft from second to second would be far too large. It was therefore necessary to provide "feel" for the pilot to enable him to control his aircraft with the minimum of acquired skill. That could be done in a number of ways; one could make it vary with the movement of the stick, with the speed of the aircraft, with the acceleration of the aircraft, or a combination of all three. A measure of "feel" was achieved by the forces imposed on the human body when the aircraft was accelerating. The merits of any "feel" system could be judged only subjectively. Most pilots were trained on aircraft with direct-operated controls, where the feel forces were a function of the aerodynamic design and varied from aircraft to aircraft. Where power-operated controls were used, on larger and faster aircraft, there was no standard against which to measure the sort of force which they supplied to the feel system. However, a device had been produced, using a spring which varied with the position of the control for movement control while, for the air-speed type of control which varied with the speed of the aircraft, they measured the ram pressure and fed that into the control force; or they could measure the acceleration by a weight and feed that by hydraulic or electric circuit to give the necessary "feel."

In making transparent panels for the pilot to see through they were faced with two sets of conflicting requirements. It was necessary to make the maximum field of view round the pilot, on all sides and upwards, as straight as possible, and to ensure that his view through the panels was perpendicular to their planes, but for the panel to have optimum aerodynamic characteristics it had to be very flat, so that the pilot would see through it at a sharp angle. Moreover, the better the transparency of a material the worse its structural properties. There was no way out of this dilemma at present.

Another problem in designing transparent panels was that the atmospheric temperature changed over a very wide range during flight and in a fighter might change by over 100 deg. Cent. in two minutes during a climb or descent. This led to large differences in temperature between the surfaces of the transparencies and the outside air, and therefore to the deposition of moisture as mist or frost, which could be got rid of by applying heat; but the methods available for heating transparencies with the intensity needed and without worsening their optical or structural properties were unsatisfactory. "Sandwich" panels had been developed, with a heated interlayer.

In the more controlled type of crash landing, such as landing with the undercarriage up on an airfield or other level area, the accelerations which occurred were rarely greater than 25*g*. There was little point, therefore, in increasing the strength and therefore the weight, of seats and their attachments above that necessary to withstand 25*g*. In civil aircraft, however, the human body was usually supported by the lap strap to withstand accelerations of about 6*g*, because the seat supports were also stressed to 6*g*, and the seats would come adrift at higher accelerations. In military aircraft the seats faced aft and were stressed to withstand the full 25*g*, so that they would support the human body up to that value in a crash.

Sir Ben Lockspeiser's presidential address to Section G, on "Progress in Aeronautical Science and Engineering," was delivered on Friday, September 5th, and abstracts from his address are reproduced on pages 349 to 351 of this issue.

(*To be continued*)

The Anglo-American Council on Productivity

In May of this year, the United Kingdom and United States sections of the Anglo-American Council on Productivity held their final joint session. As announced at that time, it was agreed that there should be formed a British Productivity Council to continue the work initiated by the Anglo-American Council on Productivity, which was established in October, 1948. The formation of a continuing organisation is also being considered in the U.S.A.

This week there has been published a document entitled *The Final Report of the Council*, giving, in four chapters, a review of what has been accomplished by the Anglo-American Council during the four years of its existence. The report is obtainable from the Anglo-American Council on Productivity, 21, Tothill Street, London, S.W.1, price 3s. 6d. It records that at the first full meeting of the council five working committees were set up, to which specific responsibilities were assigned. These committees dealt with : plant visits and exchange of production techniques ; maintenance of productive plant and power ; productivity measurements ; standardisation, specialisation and simplification in industrial production ; and economic information. During the period of the council's existence sixty-six teams have visited the U.S.A., forty-nine of them being drawn from various industries in the United Kingdom, and seventeen being specialist teams covering the elements significant to increasing productivity in all industries.

Over 500,000 copies of the reports prepared by the various teams have been distributed. The council says that these reports have been the means of stimulating firms to re-examine all the factors which improve productivity and efficiency—from methods of training, organisation and control, to the important function of packaging. It is added that the influence of the reports is not confined to this country. Other European countries, notably France and Germany, have shown great interest in the findings of the reports and have published translations of them. The reports have also been read with wide interest in the U.S.A. The council goes on to express the belief that one of the most important benefits of its work lies in the " improvement of the climate of opinion about productivity." The teams which wrote the reports found a different attitude of mind in the U.S.A., from that prevailing in many quarters in this country. Through the contacts which members of the teams made, the report comments, they are spreading over widening circles a new attitude to the importance of increasing productivity.

That influence on public opinion, it is claimed, is continuing. The " team programme " is not yet complete, and for some months to come the United Kingdom section of the council will be publishing reports. This continual repetition of the same themes, it is asserted, produces its effect, for each report widens the field in which the stimulation is experienced, and with each new publication a further impetus is given to increasing consciousness of the vital importance of productivity. After dealing at some length with the team visits, the council emphasises in its report that " they are a means, not an end in themselves." Unless they lead to action at the plant level their value will be slight. It is in the plants, the report observes, that there must be generated the real understanding and will to increase productivity by improved methods of work, both at management and employee levels. Incidentally, it is stated, as one of its continuing activities after the Anglo-American Council ceases to exist, the United Kingdom section has made arrangements for the publication of a book which will draw out the chief factors affecting productivity.

Two shorter chapters of the report deal respectively with the organisation and meetings of the council and with the work of the council. The latter sets out in some detail the methods followed in selecting the various industry and specialist teams which have visited the U.S.A., and the action taken after their return to this country to disseminate and implement their findings. These matters are further elaborated in some appendices to the report.

The final chapter of the report is concerned with the cost of the programme undertaken by the council. It is shown that in the four years 1948 to 1952 the British section has received Treasury grants amounting to £172,000 and contributions, in equal shares, from the British Employers' Confederation, the Federation of British Industries, and the Trades Union Congress totalling £30,000. From those amounts, during the four years, £179,444 has been expended, to which must be added the sum of £141,000 contributed directly by various industries in the United Kingdom which have sent teams to the U.S.A. The funds expended by the United States section—approximately £524,100—were provided by the Economic Co-operation Administration (subsequently the Mutual Security Agency). With the exception of expenses incurred for the meetings of the full council held in London, these funds were spent within the U.S.A.

An Engine Lubricating Oil Filter

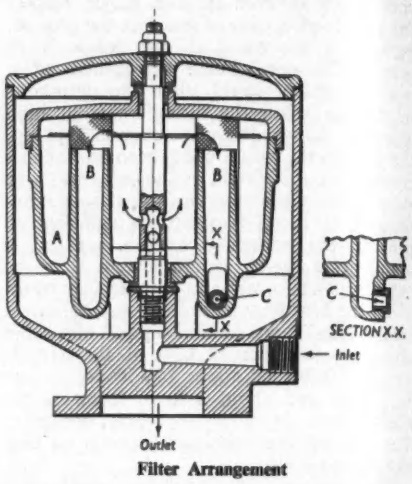
An interesting new filter unit for use in the lubricating oil systems of internal combustion engines is now being made by the Glacier Metal Company, Ltd., of Alperton, Wembley, Middlesex. At present this unit is made for use on oil engines from 60 to 120 b.h.p., and it operates on a by-pass flow from the main lubricating system. It can, however, be readily adapted for application to a wide range of other engines and for full-flow filtering if required. The filter operates on a straight-forward centrifugal principle and the rotary motion of the bowl in which dirt is removed from the oil is imparted by the pressure

Lubricating Oil Filter

of the oil flowing through the system. No filtering pack or other replaceable or renewable elements are used in the unit.

The construction of the new oil filter and its method of operation can be clearly seen from the drawing and photograph we reproduce on this page. Dirty oil from the main pressure lubricating system enters a passage formed in the base of the cylindrical body of the unit and is forced through this passage into a hollow steel spindle fixed in the centre of the body. The oil flows through a series of holes bored through the wall of this spindle into a central separating bowl *A*. The top cover of the bowl is sealed in position by a pair of nuts screwed down on studs which project through holes in the cover. The bowl is supported by bushes let into its cover and base, and it is designed to rotate freely on the central hardened steel spindle.

The bowl has two integral hollow columns or standpipes *B B* extending from its base to within a short distance below its cover. As the flow of oil from the lubricating system raises the level of oil in the bowl it flows over the top of the standpipes and fills the whole of the chamber. Each of the standpipes has at its base a nozzle *C C*, which is designed to throw a jet of oil outwards into a chamber at the base of the body. When the pressure of oil has built up in the bowl the jets come into effect and their reaction spins the bowl at a high speed. The centrifugal action thus effected causes particles of dirt suspended in the oil to impinge on the sides of the bowl, where they build up into a black rubberlike deposit. Each of the standpipes has a gauze sleeve projecting above its top and extending into close proximity with the bowl cover. These sleeves prevent the passage of particles of dirt large enough to clog the nozzles. Such particles might otherwise be carried over when starting



Filter Arrangement

up and clog the nozzles before sufficient bowl speed has been reached for the centrifugal action to become effective. The cleaned oil thrown out by the nozzles flows through a hole in the mounting flange of the filter base and into the engine sump.

The filter unit works with a minimum oil pressure of 30 lb per square inch, and the makers point out that whilst filtration will take place below this pressure, the bowl speed will be insufficient to pack the dirt to a hard layer and the working periods between cleaning are reduced. With an oil pressure of 30 lb per square inch the bowl rotates at just over 3500 r.p.m. and at 70 lb per square inch at some 6000 r.p.m. The oil flow at 30 lb. per square inch is stated to be just under 60 gallons per hour, rising to about 95 gallons an hour at 70 lb per square inch. The rotor speed and oil flow naturally depend upon the oil viscosity and temperature and the above figures are said to be typical of oil of S.A.E. 30 at 140 deg. Fah.

In the course of a recent visit to the makers' works we were shown how by the removal of one nut holding the body cover in position the bowl could be easily lifted out and the bowl cover removed after taking off two more nuts. When the bowl had been scraped clean to remove the deposit of dirt and then washed, the complete unit was re-assembled and ready for working within a few minutes.

Electrostatic Spray Painting of Tennis Racket Frames

An electrostatic spray plant, which is believed to be the first of its kind for spraying lacquer on tennis racket frames, has been installed at the Dunlop factory, Waltham Abbey. In the lacquer spraying department of this factory the tennis racket frames are carried on a conveyor through an electrode system charged at a potential difference of 132kV. In the space between the electrodes the lacquer particles acquire a charge and there is enough moisture in the wooden frames to cause them to attract lacquer particles uniformly from all directions in the interelectrode space. With this system of electrostatic spraying a substantial saving can be made in the consumption of lacquer ; the experience of the Dunlop factory suggests a saving of 40 per cent compared with hand spraying.

The Dunlop installation is based on the Ransburg electrostatic spray process, which, in recent years, has been applied to the finishing of

articles. It consists of spraying the lacquer into an electrostatic field so that an electrical charge is given to the lacquer particles. This causes them to be attracted to any article passing through the field at earth potential. As a result, the particles follow a curved path towards the article and are deposited on its surface from all directions, giving a coating of uniform thickness even when the article is irregularly shaped.

The original application of the Ransburg process was to surfaces having a high electrical conductivity, such as metal, which were to be finished with either the usual oilbound paint, cellulose or synthetic lacquers. Experiments with tennis racket frames were carried out at the Dunlop research centre to determine their normal surface conductivity, from which it was found that untreated frames, with a moisture content normal in this country, could be made to attract the lacquer particles in an electrostatic field. This work had such promising results that the decision was made to design and construct an electrostatic spraying plant for tennis, squash and badminton rackets at Dunlop's Waltham Abbey factory in co-operation with H. W. Peabody (Industrial), Ltd., U.K. owners of the rights under the Ransburg process, and the General Electric Company, Ltd.

The spraying plant consists of an open-fronted booth, in the centre of which is a U-shaped grid of metallic construction, charged to a positive potential of 130kV. The current involved is 0·09mA, giving a consumption of about 10W. An overhead conveyor, fitted with rotating grips, carries the frames at the rate of twelve per minute between the sides of the U-shaped grid, and spray guns mounted in the booth direct the paint, two guns being used for undercoat, two for colour spray, and three for the final clear lacquer coats. Alignment of these guns is not critical, as it is only necessary to produce a paint cloud in the vicinity of the U-shaped grid, and for this reason the air pressure on the spray gun is low, amounting to no more than 22 lb per square inch for atomising and 3 lb per square inch for lacquer feed.

Drying takes place at room temperature, as accelerated drying by infra-red or other kinds of heating might form a hard skin on the outside of the paint film and retard the drying. The building has no windows that open and the doors are normally kept shut as ventilation plays an important part in the process. The incoming air is drawn in by means of a fan, filtered and heated, and exceeds in volume the air removed by the exhaust fan of the spray cabinet, and there is therefore a slight pressure in the building, which prevents dust entrance. In the spray booth air flows at a speed of 100ft per minute, and the normal operating temperature in the building is 75 deg. Fah.

There are several safeguards against fire risk—the ventilation equipment reduces vapour concentrations well below explosion levels ; the electrostatic grid is provided with an electronic spark guard, tripping the supply if the earthed parts approach sufficiently near to the high-voltage electrodes to build up a dangerous concentration of the field, and the method of mounting the frames on the conveyor limits unnecessary swinging. If the ventilation fans should fail the spray guns are automatically cut off.

The conveyor has space for 297 frames, allowing a suitable margin of empty supports to facilitate loading and unloading. The painting/drying cycle is twenty-four minutes, the complete process involving passage through the spraying booth five times, once for undercoat, twice for colour coat and twice for the final clear lacquer coats. The average output is 5000 frames in two colours per week ; 45 per cent of clear and coloured lacquers, solvents and thinners are saved with the new methods, and in the future it is hoped that a 60 per cent saving will be secured in the quantity of paint applied because of the uniformity of the coats.

The plant has a high standard of cleanliness, because a large proportion of the lacquer particles are attracted to the frames ; the electrostatic grid remains clean because its opposite charge repels the particles. We learn that the exhaust ducts did not require cleaning during the first year, and the sanded floor, although rebrushed every day, seldom requires renewal.

Michigan State Ferry "Vacationland"

The ferry "Vacationland" of the Michigan State Highway Department entered regular service in the Straits of Mackinac, carrying vehicles and passengers over the 7-mile run between St. Ignace and Mackinaw City, Michigan, U.S.A., early this year. The vessel is the first diesel-powered, ice-breaking ferry to go into operation on the Great Lakes and is claimed to be the largest double-ended ferry boat in the world. The ship is driven by four direct-reversing diesel engines through electric slip couplings and has a normal service speed of 15 m.p.h.

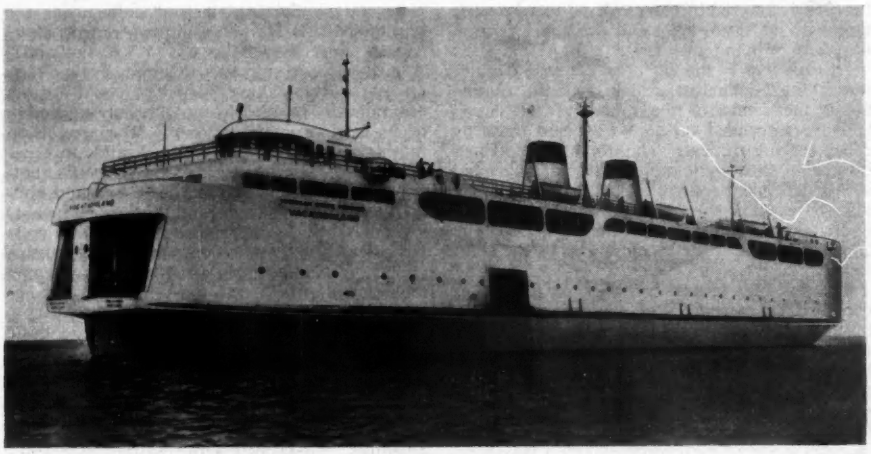
THE "Vacationland," illustrated in our photograph, was designed and constructed by the Great Lakes Engineering Works at River Rouge, Michigan, to meet the requirements of the Michigan State Highway Department, and under the special survey of the American Bureau of Shipping for ice-breaking service on the Great Lakes and to meet all inspection requirements of the U.S. Coast Guard. It is powered by four 2360 h.p. Nordberg direct-reversing diesel engines and has capacity for 150 vehicles, carried in eight lanes on one car deck, and 650 passengers. The principal dimensions of the ferry are as follows :—

Length on deck	360ft
Length on keel	330ft
Beam, moulded	73ft 6in
Beam over fenders	75ft
Depth moulded to car deck	25ft 3in
Depth moulded to spar deck	43ft 4in
Least clearance over car deck	14ft 6in
Shaft horsepower, normal rating	7440
Maximum continuous shaft horsepower ...	9300
Normal operating speed, m.p.h.	15

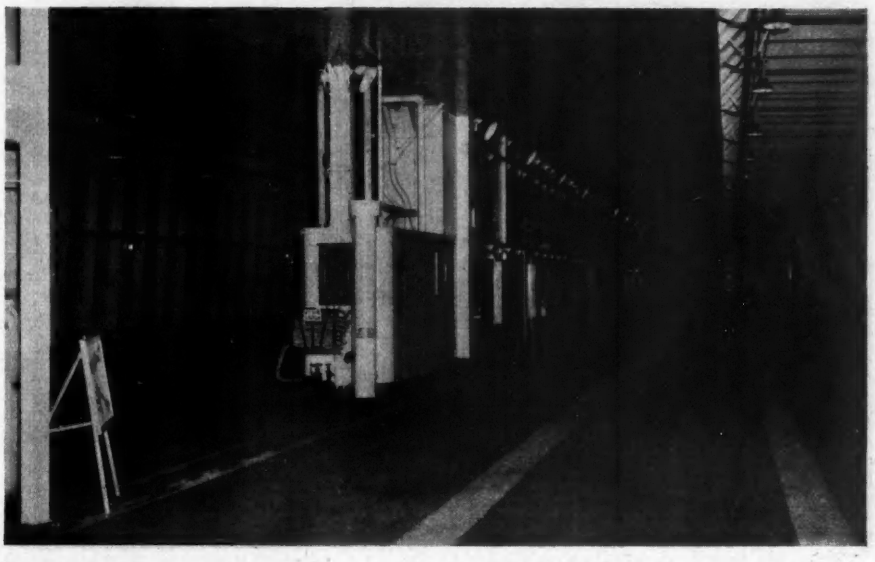
The hull of the vessel is of welded construction, designed especially for navigation in ice and has twelve transverse water-tight bulkheads, so spaced that the vessel has a two-compartment standard. The scantlings are particularly heavy for operation in heavy ice. Passenger accommodation and observation rooms have been provided in a steel house above the car deck, which we illustrate, and on the deck above are two pilot houses and the crew's quarters. The ship is part of the programme of the Michigan State Highway Department to relieve the traffic bottleneck which has developed in the Great Lakes area, and to facilitate the handling of the new vessel as well as the existing end-loading ferries, new docks have been constructed at both St. Ignace and Mackinaw City.

Hull Construction

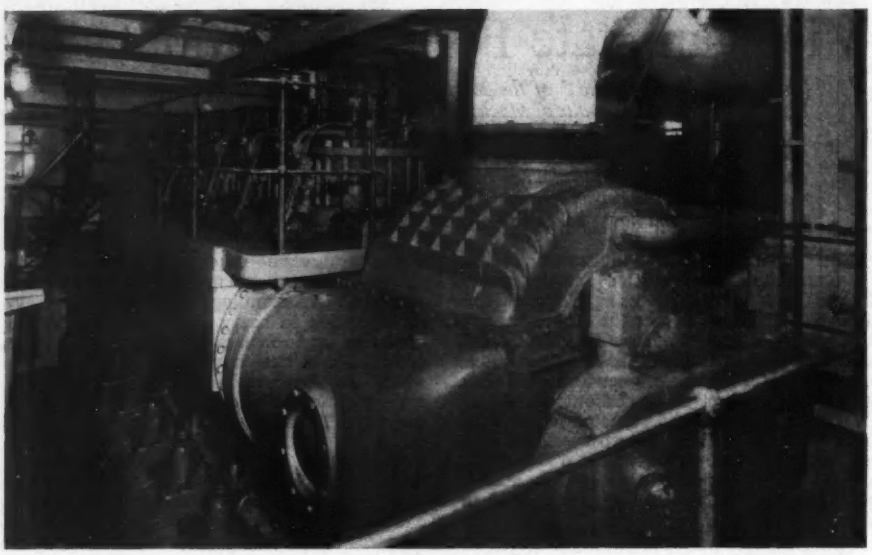
The rudders at each end are identical and interchangeable, and have cast steel frames and are filled with pine. The main deck is designed to carry a concentrated load on one beam of two lorries abreast, each with an axle load of



Ferry "Vacationland"



Car Deck



Main Propulsion Engine

32,000 lb on the same beam. Three gangway doors are fitted on each side and spaced so that any adjacent two match the ramps in the docks at Mackinaw City and St. Ignace. The lower 10ft of each door hinges outboard at the main deck level and the upper portion hinges inboard. The lower portion, which serves as a gangway for cars, is lowered by cables reeved to an electric motor-driven drum hoist and the upper portion is raised by hand tackle.

At each end of the car deck are semi-circular doors, fitted in halves, which open by rotating about the centre of the radius of the curve, and are suspended on an "I" beam track by roller bearing trolleys. The doors are operated by a cable, sheave and motor-driven arrangement with independent control of each half; and may also be opened manually. Sliding water-tight doors are fitted in the bulkhead between the engine-rooms and at the entrances to the shaft tunnels.

The outside vertical surfaces of all spaces occupied by passengers or crew are lined with insulating material 3in thick and exposed decks over these spaces are insulated in a similar manner with rigid material 4in thick. A complete sewage treatment plant is provided aboard ship, preventing the discharge of any raw sewage from the vessel. The navigating equipment includes a Sperry gyro compass and a Raytheon radar system, and for life-saving purposes, six 22ft metal life-boats, each having a capacity of twenty-five persons, are supplied and carried under mechanical davits, and handled by motor-driven boat winches.

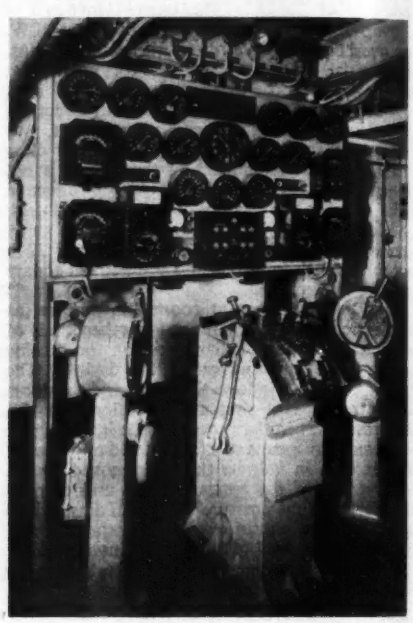
Propulsion Machinery

Several important factors influenced the selection of the Nordberg direct-reversing diesel engines for propelling the "Vacationland." A dual-purpose ship was required, having high power for ice-breaking, but which could operate economically in open water with only a fraction of its total propulsion power. The propulsion machinery had to be extremely flexible in order to adjust the operating time-table to the fluctuating traffic loads, for summer week-end and holiday traffic across the Straits of Mackinac is extremely heavy, and service at such times must be faster than on week-days, when the burden is light. In addition to satisfying the foregoing requirements, the vessel must have low operational and fixed charges.

Following upon the completion of the basic design of the ship, comparative operating costs of the three proposed propulsion systems, namely, oil-fired steam uniflow, diesel-electric and diesel direct drive with electric couplings, were calculated on the basis of the operating schedules. These costs were predicted on guaranteed fuel and lubricating oil consumptions, anticipated maintenance, fixed costs and charges, and the salaries of the operating personnel, and from the detailed studies thus made it was concluded that the direct diesel engine drive would show a substantial saving over the reciprocating steam and diesel-electric propulsion.

The main machinery consists of four Nordberg two-cycle, direct-reversing diesel engines of the trunk piston, solid injection design, each having eight cylinders of 21½in bore and 31in stroke, and being fitted with one engine-driven Roots-Connersville scavenging air blower. Each engine, one of which we illustrate, together with a photograph of the control panel, develops a continuous rating of 2360 b.h.p. at 165 r.p.m. and the total installed normal shaft horsepower is 9300, which is equally divided between the four propellers. Full power on all screws will be used only in severe ice conditions in the Straits. For open-water service the normal running is maintained with reduced power, using two engines at a time.

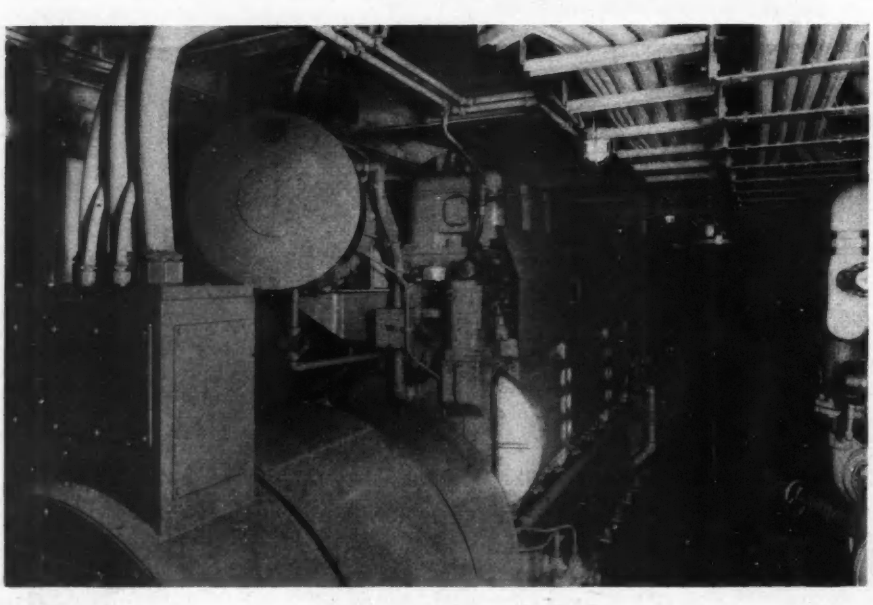
The machinery space is divided into two separate water-tight engine-rooms which occupy a total length of about 88ft in the midship portion of the ship. Both engine-rooms are arranged so that ample room is provided for access to the main engines and all auxiliary machinery. The main engines are arranged in pairs, two in the after space and two in the forward engine-room.



Engine-Room Control Panel

Starting air for the engines is stored in four receivers, supplied by three air compressors, each having a capacity of 74 cubic feet per minute at 250 lb per square inch, at which pressure air is delivered to the starting valves. Two cooling water systems have been provided—one for each pair of engines. Each consists of a jacket fresh water pump and a raw lake water pump mounted on a sub-base with a common driving motor. The lake water suction is normally taken from a system composed of twelve interconnected sea cocks with steam thawing connections, which are spaced along the bottom of the ship. In the event of these connections becoming plugged with ice, the space between the ship's shell and tank top under the engine-rooms will be used for the storage and cooling of lake water used in the heat exchangers for jacket water and lubricating oil. Spare pump sets have been provided for both the raw water and soft water systems.

Intake air for the Nordberg propulsion engines may be taken direct from the atmosphere, from the engine-rooms or from the atmosphere through chambers passing around exhaust mufflers and piping for preheating purposes. This flexible arrangement has been designed to



Diesel-Electric Generating Set

facilitate engine starting and to ease the effects of severe cold on the engines during the winter season. The specially designed intake air duct and valve system is manually operated remotely from the engine-room level. Seven tanks, situated fore and aft of the engine-rooms, with a total capacity of 147,719 U.S. gallons provide heavy fuel oil storage for the main engines and there are four tanks which have a capacity for storing 26,091 U.S. gallons of light fuel oil for the auxiliary generating engines. The main engine fuel oil is taken from heated bunker tanks and is heated, centrifuged and supplied either to a heated clean oil bunker tank or to the heated daily service tanks. Heaters are provided between these tanks and the main engine fuel headers, heat being supplied from steam generated by the ship's heating boilers. The entire fuel system is designed to facilitate the burning in the main propulsion engines of viscous and low-quality residue oils from the many native wells and refineries in the central area of the state of Michigan. Individual lubricating oil sumps, pumps, coolers, strainers and filters are provided for each of the four propulsion engines and the main engine lubricating oil sumps have steam heating coils.

The demand for auxiliary electric power is supplied by three Nordberg diesel generating sets, illustrated opposite, which are situated adjacent to the two main propulsion engines in the forward engine-room. The engines for these sets are of four-cycle supercharged design, with seven cylinders of 9in bore and 11½in stroke, each rated to develop 560 b.h.p. at 720 r.p.m. and directly connected to a 385kW, 230V, three-phase, 60 c/s Westinghouse generator having a direct-connected exciter. The cooling water system has been designed so that jacket water, from the auxiliary engine in use, is circulated through the two main engines which are stopped. These two engines, thus, are kept warm and at the same time cool the auxiliary engine jacket water. The circulation of the auxiliary engine jacket water to either pair of stopped main engines is manually controlled by valves in the piping system, which includes all three auxiliary and four main engines.

Each propulsion engine drives a three-bladed bronze propeller, of 12ft 3in diameter by 9ft 3in pitch, through a Westinghouse electro-magnetic slip coupling having a rating of 2360 h.p. at 165 r.p.m., and a Kingsbury thrust bearing. The inner member of the coupling has a weight of 9000 lb and a moment of inertia of 89,000 lb per square foot ; and its outer member a weight of 26,150 lb and a moment of inertia of 395,750 lb per square foot. The performance provided by the electric couplings was considered to be particularly desirable in ferry service, since the couplings act as clutches, which permit bow propellers to " windmill " when the bow engines are not in use and the vessel is being propelled by the two after propellers. Furthermore, when the vessel is working in heavy ice, the couplings damp any shock torques which may be transmitted from the propellers through the shafting to the engines. Because of the ability of the electric slip couplings to connect or disconnect the propeller drive rapidly through simple control of the excitation circuit, easy and quick starting and reversing of the main engines is made possible, resulting in a flexible and highly manœuvrable ship. Normally, coupling excitation is applied in two steps, during starting or reversal of engines, reduced excitation is applied for a short interval with corresponding reduced torque being transmitted to eliminate the possibility of engine stalling during such manœuvring, and full excitation comes on automatically after a predetermined time interval. Under full excitation, each coupling will transmit the normal load with a slip of 1·15 per cent. The coupling is capable of developing 175 per cent of full load torque, which is sufficient to stall the engine in case the propeller becomes jammed in the ice, and also allows the application of almost instantaneous high torque, which might be required when attempting to free a propeller which is stopped by the ice. In this circumstance the engines are started and brought up to about two-thirds speed with couplings disengaged, and the maximum coupling excitation is then applied directly by the operator pushing a control button. For dead slow operation of the propellers, a second and greater reduction in excitation is available under manual control by the operator. This allows the coupling to operate at high slip for indefinite periods with a very low torque transmission and a low propeller speed. With the main engines working at 100 r.p.m., the propeller speed can be varied between 20 and 100 r.p.m. as desired.

The coupling excitation has been made as reliable as the other electrically-driven auxiliaries, which include the steering gear. As a measure of protection, provision has been made so that, when any two a.c. auxiliary generators are in operation and either of them fails, the ship's load will be automatically released by the tripping of feeder circuit breakers, in the order of importance, while maintaining the ship's functions of steering, main engine auxiliaries, electric coupling excitation and other vital lines up to an electrical overload of 110 per cent.

The main engines and the electric couplings are controlled from two central pedestals, one in the after engine-room and the other in the forward engine-room, the operating signals being transmitted from both pilot houses to the control pedestals by conventional engine-room telegraphs augmented by " wrong direction " alarms.

Plastic Collapse Loads for Plane Frames*

By B. G. NEAL† and P. S. SYMONDS‡

No. II—(*Concluded from page 319, Sept. 5th*)

In suitable instances the application of plastic design methods to plane frames of ductile material, such as mild steel, leads to more rational and economical designs. These design methods are based on the calculation of the loads at which a structure collapses owing to excessive plastic deformation. Such collapses occur when a sufficient number of plastic hinges have formed to transform the structure into a mechanism, so that deflections can continue to grow, due to rotations of the plastic hinges, while the loads remain constant. In this paper the theoretical basis of a new technique for determining plastic collapse loads is discussed and typical calculations for a pitched-roof portal frame are given.

Three-Bay Pitched-roof Portal Frame

To illustrate the scope of the technique which has been described in detail, calculations for the three-bay frame whose dimensions and loads are as shown in Fig. 12 will now be outlined briefly. As before, all the loads are assumed to be uniformly distributed, and the vertical loads of 3·60 tons on each rafter member are due to dead and superimposed loads, the remaining loads being wind loads. In the first instance, it will be assumed that all the members of the frame are of the same cross-section, with a fully plastic moment M_p.

Design for Dead, Superimposed and Wind Loads.—For this loading case, a load factor of 1·4 will be used. Examination of Fig. 12 shows that twenty-three bending moments are needed to specify the bending moment distribution for the entire frame, which has nine redundancies. There must therefore be fourteen independent mechanisms. Eight of these mechanisms are accounted for by the simple beam type of failure mechanism (as in Figs. 5(*a*), (*b*), (*c*) and (*d*), for example) occurring in the members *AB*, *BC*, *CD*, *DF*, *FG*, *GI*, *IJ* and *JK*. For these mechanisms, the highest value of M_p is obtained for the member *GI*, this value of M_p being 7·28 tons-ft. Two mechanisms must be counted for rotations of the joints *D* and *G* in Fig. 12, for it will be realised that for each of these joints there will be an equation of rotational equilibrium between the three bending moments acting on the joint. There will also be one sidesway mechanism, with plastic hinges in the vertical members at *A*, *B*, *D*, *E*, *G*, *H*, *J* and *K*, for which the corresponding value of M_p is 1·69 tons-ft. The remaining three independent mechanisms may be chosen in a variety of ways, but the three mechanisms illustrated in Figs. 14 (*a*), (*b*) and (*c*) are probably the most convenient for the present purpose. It will be seen that each of these mechanisms is basically of the same type, with the rafters collapsing in one bay and thus causing sidesway of those parts of the frame lying to the right of the collapsing bay. For reference, the plastic hinge rotations are shown in these figures in magnitude only. It will be noted that the joints *D* and *G* remain unrotated in each of these mechanisms, since in each case any rotation of these joints would increase the work absorbed in the plastic hinges and so reduce the value of M_p.

The virtual work equations for these three mechanisms are found to be :—

Fig. 14(*a*)—
$$7\cdot32\theta M_p = 123\cdot5\theta, \quad M_p = 16\cdot9 \text{ tons-ft} \quad . \quad (16)$$

Fig. 14(*b*)—
$$10\cdot64\theta M_p = 120\cdot4\theta, \quad M_p = 11\cdot3 \text{ tons-ft} \quad . \quad (17)$$

Fig. 14(*c*)—
$$13\cdot96\theta M_p = 115\cdot1\theta, \quad M_p = 8\cdot25 \text{ tons-ft} \quad . \quad (18)$$

The highest value of M_p obtained from the independent mechanisms is thus 16·9 tons-ft for the mechanism of Fig. 14(*a*). It is easily seen that this value of M_p will not be increased by combination with any of the simple beam mechanisms, for which the highest value of M_p was found to be 7·28 tons-ft. It is also clear that the sidesway mechanism, for which M_p was found to be only 1·69 tons-ft, cannot be combined with advantage. It remains to investigate possible combinations of the three mechanisms.

The mechanisms of Figs. 14(*a*) and (*b*) can

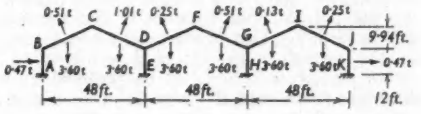


Fig. 12

be combined if the hinge rotations and displacements in the mechanism of Fig. 14(*a*) are all multiplied by a factor of 1·66, and then superposed on the mechanism of Fig. 14(*b*). This enables a clockwise rotation, of magnitude 1·66θ, to be given to joint *G*, which cancels plastic hinge rotations of 1·66θ in the members *GI* and *GH* at this joint, while increasing the plastic hinge rotation in the member *GF* by 1·66θ. This produces a net reduction in the virtual work absorbed of $1\cdot66\theta M_p$. The resulting virtual work equation for this combination is then seen from equations (16) and (17) to be :

$$1\cdot66 \,.\, 7\cdot32 \,.\, \theta M_p + 10\cdot64\theta M_p - 1\cdot66\theta M_p = 1\cdot66 \,.\, 123\cdot5\theta + 120\cdot4\theta$$
$$21\cdot10 M_p = 325\theta$$
$$M_p = 15\cdot4 \text{ tons-ft} \quad . \quad . \quad . \quad (19)$$

This value of M_p is smaller than the value of 16·9 tons-ft obtained for the mechanism of Fig. 14(*a*), and it is clear that no other possible combination of the three mechanisms of Figs. 14(*a*), (*b*) and (*c*) will yield a larger value of M_p. It is therefore concluded that the mechanism of Fig. 14(*a*) is the actual collapse mechanism. This solution will not be adjusted to allow for the possible occurrence of plastic hinges at cross-sections other than the ends and centres of the members, for when the dead plus superimposed loading case is considered, it will be found that the wind loading case does not govern the design.

An interesting feature brought out by this analysis is that there are only four plastic hinges in the collapse mechanism, whereas the frame has nine redundancies. At collapse, therefore, only the right-hand bay of the frame is statically determinate, and in carrying out a statical check the bending moment diagram for the other two bays could not be constructed directly. Instead, it would be necessary to carry out a trial and error investigation to show that the six redundancies of these two bays could be chosen in at least one way so as to produce a resultant bending moment diagram in which the fully plastic moment was not exceeded anywhere in the frame. This would be a tedious process, and in view of the fact that this is not the loading case which governs the

---

* Paper presented at the Fourth Congress of the International Association of Bridge and Structural Engineering.

‡ Engineering Department, Cambridge University.
† Brown University, Providence, R.I., U.S.A.

design, the check is probably not worth performing.

Design for Dead and Superimposed Loads.—A load factor of 1·75 will be used for this loading case. The loading, consisting merely of the vertical loads of 3·60 tons on each rafter, is symmetrical, so that the collapse mechanism and the bending moment distribution at collapse must also be symmetrical. It will be seen that the values of eleven bending moments will specify the bending moment distribution for the entire frame, and that owing to symmetry there are only five redundancies. There are thus six independent mechanisms, which must all be symmetrical. Three of these mechanisms are the simple beam type of failure mechanism in the pairs of rafters *BC* and *IJ*, *CD* and *GI*, and *DF* and *FG*. For each of these mechanisms, the corresponding value of M_p is 9·45 tons-ft. One mechanism must be counted for rotation of the joints *D* and *G*. The remaining two mechanisms are most conveniently chosen as the mechanisms shown in Figs. 14(*d*) and (*e*).

The virtual work equations for these two mechanisms are :—

Fig. 14(*d*)—

$$14\cdot64\theta M_p = 302\cdot4\theta, \quad M_p = 20\cdot6 \text{ tons-ft} \quad . \quad (20)$$

Fig. 14(*e*)—

$$10\cdot64\theta M_p = 151\cdot2\theta, \quad M_p = 14\cdot2 \text{ tons-ft} \quad . \quad (21)$$

The only possible combination of these mechanisms is obtained if the hinge rotations and displacements in the mechanism of Fig. 14(*d*) are all multiplied by a factor of 0·83, and then superposed on the mechanism of Fig. 14(*e*). This enables a counter-clockwise rotation of the joint *D*, of magnitude 0·83θ, to be made, thus cancelling plastic rotations of 0·83θ in the members *DC* and *DE* at this joint, while increasing the plastic hinge rotation in the member *DF* by 0·83θ. This produces a net reduction in the virtual work absorbed of $0\cdot83\theta M_p$, and a similar reduction can be achieved by a clockwise rotation of the joint *G*. The resulting virtual work equation is then seen from equations (20) and (21) to be :—

$$0\cdot83 \,.\, 14\cdot64\theta M_p + 10\cdot64\theta M_p - 1\cdot66\theta M_p = 0\cdot83 \,.\, 302\cdot4\theta + 151\cdot2\theta$$

$$21\cdot16 M_p = 402\theta$$

$$M_p = 19\cdot1 \text{ tons-ft} \quad . \quad . \quad . \quad . \quad (22)$$

This value of M_p is less than the value of 20·6 tons-ft, which was found to correspond to the mechanism of Fig. 14(*d*). It may also be checked

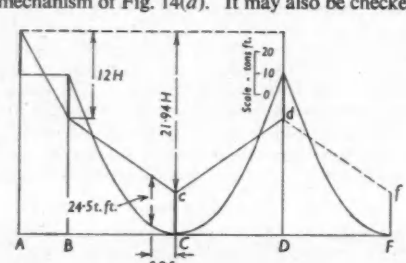


Fig. 13

that the beam collapse mechanisms for the rafters cannot be combined with any of these mechanisms to produce a value of M_p greater than 20·6 tons-ft. The mechanism of Fig. 14(*d*) is thus the actual collapse mechanism, subject to alterations due to the occurrence of plastic hinges at positions other than at the ends and centres of the members. A statical check will now be made which will also serve to indicate such alterations in the position of the plastic hinges.

Check by Statics.—Because of symmetry, the statical check need only be made for one half of the frame, say, the left-hand half. For this portion of the frame, the free bending moment diagram is constructed by imagining cuts to be made at the apices *C* and *F*. The resulting diagram is given in Fig. 13, for the case in which the loads have been multiplied by the load factor of 1·75. It will be seen that there is no free bending moment in the vertical member *DE*, and the diagram for this member has not been drawn.

For the members *AB*, *BC* and *CD* the redundant bending moment diagram may be constructed directly, since the bending moment has its fully plastic value at *A*, *B*, *C* and *D*. The horizontal thrust *H* in this bay can be calculated from the vertical intercept between the redundant bending moment diagram and the dotted line in Fig. 13. In each case a value of 3·44 tons is obtained, thus checking the solution. Since the centre bay of the frame is not statically determinate at collapse, the redundant bending moment diagram for the member *DF* cannot be constructed directly. However, it is clear from the symmetry of the diagram about *D* that one possible redundant bending moment line for *DF* is the dotted line *df* shown in Fig. 13, where *fF* represents the calculated fully plastic moment of 20·6 tons-ft. This line has a slope equal in magnitude to the line *cd* in Fig. 13, and this corresponds to the same value of the horizontal thrust of 3·44 tons

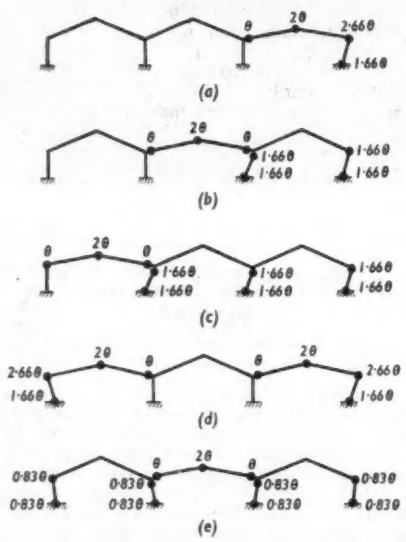


Fig. 14

which was found for the left-hand bay of the frame. If this were the actual redundant moment line for the member *DF* at collapse, it follows that there would be no resultant horizontal thrust on the vertical member *DE*, which would thus have zero bending moment throughout its length. It is therefore possible to construct a bending moment diagram for the entire frame in which the fully plastic moment is not exceeded at any cross-section, except within the spans of the rafter members. This confirms the solution found by the virtual work analysis.

It will be seen from Fig. 13 that plastic hinges will actually occur in the rafter members at distances of 5·9ft from the apices *C* and *G*, rather than at these apices. When this is taken into account, the value of M_p is 21·9 tons-ft.

The statical check reveals the fact that the internal stanchions *DE* and *GH* need not be called upon to participate in the collapse mechanism, for it is possible to construct a resultant bending moment diagram in which these members are free from bending moment. These members, which were assumed in the first instance to possess a fully plastic moment M_p, thus function merely as props which hold up the rafter members. They could therefore be designed as compression members, and made of hollow tubing.

Conclusions

The merits of the method of design described in this paper can really be appreciated only by applying the method to practical examples. However, the foregoing examples serve to illustrate some of its advantages. The outstanding feature of the method is, of course, its rapidity. This is mainly due to the ease with which corresponding values of M_p can be obtained by the principle of virtual work, and this in turn is due largely to the fact that there is no need to establish sign conventions when applying this principle, since the virtual work absorbed in a plastic hinge must always be positive. A further important advantage of the method is that it enables solutions to be found without difficulty for those cases in which the entire frame is not statically determinate at collapse.

Oil Refineries Near Bombay

(By our Indian Correspondent)

India is notoriously poor in oil resources Her only sizeable oil wells are in Assam, the north-eastern state bordering Burma, but the relatively small production in the area has required only some 5000 barrels per day refining capacity and this has been sufficient to handle all the indigenous crude oil produced in the country. This figure, which is roughly equivalent to about 200,000 tons per annum, represents only 7 per cent of the country's total annual internal consumption of 2,800,000 tons in 1950. The Government, therefore, has been faced with the problem of importing sufficient quantities of petroleum products to meet the growing demands and at the same time minimising the expenditure of hard currency. Also, the oil companies operating in India were not very eager to import capital into the country without sufficient backing from the Government and specific guarantees against nationalisation.

After negotiations lasting over three years, the Government of India entered into an agreement last November with the Standard-Vacuum Oil Company, covering the construction of a modern refinery at Trombay, near Bombay. This was soon followed by another agreement with the Burmah-Shell group of companies on much the same lines and also involving another refinery at the same place. It is reported that negotiations are now proceeding with the Caltex group of companies for another refinery somewhere on the east coast, probably near Madras. The capacity of the Standard-Vacuum refinery will be 1,000,000 tons per annum, that of the Burmah-Shell about 2 million tons, and the Caltex may be able to add another 800,000 tons. Thus, by 1956, when the refineries are expected to begin production, India's refining capacity will be about 4,000,000 tons per annum, that is, nearly twenty times the present capacity. It is expected that by that time India's internal consumption will have risen to about 4,200,000 tons per annum.

The question of large-scale foreign capital investment has strong political overtones and naturally the Government has been reluctant to divulge the details of the agreements beyond stating that " in order to facilitate the installation projects, they have given certain assurances, including exemption from compulsory acquisition for a period of twenty-five years and from certain sections of the Industries (Development and Regulation) Act. The companies will be free to make their own arrangements for the import of crude oil and for the distribution of refined products in India ; also to export such products as may not be required for the Indian market." On their part, the companies have given assurances which relate to the training and employment of suitable nationals where available, in all ranks ; use of Indian crude when available ; use of Government tankers (if any should be acquired) ; and non-use of tankers of countries discriminating against India. The Burmah-Shell Refineries, Ltd., a new company registered to own and operate the refinery, will have an authorised capital of Rs.25 crores (about £19 million), of which Rs.2 crores will be offered as preference shares to Indian investors. The Standard-Vacuum Oil Company will invest about Rs.16 crores and the Caltex group a somewhat smaller sum. The total investment spread over the next four years, therefore, will be of the order of Rs.55 crores, and is expected to save India about Rs.3 crores of foreign exchange annually.

Preliminary work in connection with the construction has already commenced at Trombay, a vast swampy area about 15 miles north-east of the city of Bombay. Trombay is likely to become a fairly important industrial centre on the west coast of India, for in addition to the two refineries, plans are going ahead for a new thermal power station with an ultimate installed capacity of 100MW. The three plants will act in unison for, if the investigations now being undertaken are promising, the power station will use waste gases from the refineries, which, in turn, will get their supply from the station. All three are expected to be ready by 1956, the last year of India's first five-year plan.

Industrial and Labour Notes

The T.U.C. and Wages

The Trades Union Congress—in the course of its annual session at Margate last week—debated resolutions on wages policy on Thursday. Mr. Lincoln Evans was the principal spokesman for the general council, and, ultimately, the Congress approved by a large majority its general council's statement on trade unions and the economic situation.

That statement, it may be recalled, emphasised the consequences of big increases in wages at the present time, pointing out that they were bound to raise costs. Moreover, the statement declared, it was likely that the largest wage increases would be secured in the industries whose products were most in demand at home and abroad, a likelihood that was increased by the fact that broadly speaking it was in those industries that profits were highest. In other words, industrial costs were likely to increase most in precisely those industries upon which the country depended most for exports at the present time.

In his speech to the Congress, Mr. Lincoln Evans said that it was misleading to allow trade unionists to believe that all pay increases could be met from profits, for if that were true, the recent increases in the cost of coal and transport would have been unnecessary. The position broadly was that trade unionists paid one another's wage increases. The general council, Mr. Evans continued, was not asking the Congress to endorse a policy of wage restraint which would be unreal in present circumstances. But, he added, if the trade union movement objected to interference with the existing negotiating machinery, it must see to it that wage negotiations did not endanger the national economy. On the other hand, Mr. Evans commented, employers must not be allowed to stultify negotiations by refusing even to consider justifiable claims and relying on the Government's statements on wages as an argument.

Dispute at a Vehicle Building Works

At the end of last week there was issued the report of a committee of investigation set up by the Minister of Labour to inquire into a dispute between Park Royal Vehicles, Ltd., and the National Union of Vehicle Builders and the Amalgamated Society of Woodcutting Machinists. Professor D. T. Jack was the chairman of the committee, which held its inquiry in private on August 28th.

A strike at the Willesden works of Park Royal Vehicles, Ltd., began on July 2nd when about 1000 men stopped work. Prior to that date, twenty-two men had stopped work over a piecework price dispute, and as a result of that stoppage the firm shortly afterwards had to suspend seventy-eight men owing to the dislocation of production. The full-scale strike followed.

In its report, the committee expresses the opinion that both Park Royal Vehicles, Ltd., and the joint wages board of employers for the vehicle building industry, to which the firm is affiliated, have acted constitutionally and have broken no agreements. On the other hand, the report states, the shop committee at the factory, the National Union of Vehicle Builders and the Amalgamated Society of Woodcutting Machinists have contravened the provisions for avoidance of disputes laid down in the national agreement to which they and the employers' federation are parties. The committee finds also that the first workers to go on strike—the twenty-two who stopped work on account of a piecework price dispute—broke the constitution of the bonus scheme and also the national agreement by withdrawing their labour while negotiations were in progress. Delay by the district union official in making personal contact with those strikers is criticised by the committee. The committee agrees that after the strike of the twenty-two had been in progress for eight days, it was necessary for the firm temporarily to suspend seventy-eight men because of consequent dislocation of production. In the negotiations for a resumption of work, the management made substantial concessions with a view to reducing the delay before the temporarily suspended men would be re-engaged, and the committee considers that the management's last offer—that the delay should in no case exceed forty-eight hours—should have been accepted. In the report, union officials are criticised for their failure to submit immediately to a full meeting of workpeople terms for resumption agreed upon between union officials and the management.

The committee has recommended that the unions should accept, and instruct their members to accept, resumption on the terms of the management's last offer, i.e. that all workers should resume immediately, except the seventy-eight temporarily suspended, and that the latter should resume not more than forty-eight hours later, the management undertaking to use its best endeavours to shorten that period wherever possible. Negotiations on the disputed piecework price, the report adds, should at once be resumed at the point at which they were interrupted by the strike.

Labour in the Indian Steel Industry

The annual meeting of the Tata Iron and Steel Company, Ltd., was held in Bombay on August 28th, and, in the course of his speech, the chairman, Mr. J. R. D. Tata, described the labour situation in the undertaking as satisfactory. Mr. Tata went on to say that the company's labour statistics for the year indicated a large increase both in the average income per employee and in the labour cost per ton of finished steel. The latter, he observed, had now reached a level which left no margin for further increase in earnings *per capita* except through increased productivity. In that connection, Mr. Tata stressed the need for a reduction in the number of men employed, which, he said, would be achieved gradually by not filling vacancies and by absorbing surplus men in new plants or departments.

Mr. Tata said that while the average annual income per employee at Jamshedpur had gone up by 33 per cent, the output of finished steel had increased by only 13 per cent, which was still 6 per cent below the 1939–40 level, and the board felt that the time had now come to insist that any further increase in payments and benefits to labour must be accompanied by an increase in individual output. Mr. Tata thought that one of the chief difficulties in obtaining labour's co-operation was the weakness of the trade union movement in India, when compared with countries which were more advanced industrially. No lasting improvement was possible, he said, unless trade unions were better organised and consolidated so that employers could make with them collective agreements which were equally enforceable on both sides. The tendency of political parties to control trade unions as part of their bid to canvass labour support in elections led to the unhealthy multiplication of unions, often within the same industry, making conflicting demands on managements, with the result that the real and constructive aspect of labour organisation often took a second place.

Safety Footwear

At the press conference in London on Tuesday last, a statement was made by Mr. Gordon Weston, technical director of the British Standards Institution, about safety boots and shoes for workers in industries where foot hazards are common. British Standard 1870, which has recently been published, covers safety footwear capable of ensuring a high degree of protection under all conditions encountered in industrial practice. Footwear made to this specification will bear the British Standards Institution's "kite" mark. Mr. Weston explained that the Institution would issue licences to manufacturers to apply the mark only after their footwear had been fully examined and tested, and their works visited to ensure that the regular methods of production, supervision and testing were adequate to maintain the standard required by the specification. In the work of inspection and testing, Mr. Weston added, the B.S.I. would have the help of the British Boot and Shoe and Allied Trades Association.

The Parliamentary Secretary to the Ministry of Labour, Mr. Harold Watkinson, who also spoke at the conference, said that workers in all industries, especially those in heavy engineering, shipbuilding and dockside work, as well as those in mines and quarries and in railway transport, which latter did not come under the Factories Acts, were always liable to foot injuries. These injuries were most frequently incurred by the worker being trapped by loads moving over the workplace floor, or by being struck by falling articles dropped from the hands, the bench or the machine.

The Coal Board's Quarterly Statistical Statement

The National Coal Board has published this week a statistical statement on the costs of production, proceeds and profit or loss of collieries for the second quarter of this year. It shows an estimated net deficit for the quarter of £727,563, as although the profit on the Board's undertaking has been estimated at £3,172,437, provision has had to be made for a sum of £3,900,000, representing interest payable to the Minister of Fuel and Power.

In presenting the statement, the National Coal Board has pointed out that the financial results for the second quarter reflect the effect of the Easter and Whitsun holidays. There was also an increase in the cost of roof supports, general stores and repairs, brought about mainly on account of higher prices. During the quarter, the statement shows, the saleable coal raised from the Board's mines amounted to 52,136,269 tons, of which 48,530,091 tons were disposable commercially, the remainder being taken up for mine consumption and as miners' coal.

Proceeds from the sale of coal during the quarter totalled £149,852,451 (57s. 5·8d. per ton) and total production costs were £146,705,014 (56s. 3·3d. per ton). Of the total costs, wages, including holiday pay and allowances in kind, required £92,257,500 ; roof supports, general stores and repairs, £25,936,636 ; coal and power consumed, £7,547,509 ; and other costs (including depreciation), £20,963,369. The average cash earnings per week were: face workers, £12 3s. 6d.; and all workers, £10 8s. 9d.; the value of allowances in kind being given as 9s. 1d and 8s. 8d., respectively.

Private Trading in Lead

As already announced, the Ministry of Materials will make no new contracts after September 30th for the sale of imported lead to consumers. In order to facilitate the resumption of private trading, the London Metal Exchange is to reopen for dealings in lead on October 1st, and the Board of Trade has now announced arrangements for the import and export of lead.

The arrangements for the import of unwrought lead in pigs, ingots, blocks, bars, slabs or cake, but not alloys of lead, are as follows : members of the London Metal Exchange who participate in the Bank of England exchange control scheme will be granted open individual licences valid for importation from any source. Consumers who wish regularly to import substantial quantities of lead, otherwise than through the medium of the Exchange, will be granted open individual licences valid for appropriate sources of supply. Applicants should state the quantities they expect to import in the ensuing twelve months and the main sources from which they expect to purchase. Such open licences will be granted on condition that returns showing full details of both value and source of imports are made to the Board of Trade at monthly intervals. Other traders wishing to import lead should make application for a licence in respect of each individual transaction. All applications should be addressed to the Board of Trade, Import Licensing Branch, Romney House, Tufton Street, London, S.W.1.

Notes and Memoranda

Rail and Road

SWEDEN'S MOTOR VEHICLES.—According to a survey made recently by Svenska Handelsbanken, there were approximately 410,000 cars, lorries and buses on the roads of Sweden at the end of last year. This, it is stated, represented an increase of about 65 per cent on the 1939 figure.

THE END OF ANOTHER RAILWAY CLASS.—We are informed by British Railways that locomotive No. 40383, the last of the old Midland Railway 4–4–0 non-superheated Class 2 passenger engines, has been withdrawn from stock for breaking up. This engine, which was designed by S. W. Johnson and built in 1888, was one of a batch of ten, the original numbers being 1808 to 1817. It had 6ft 6½in diameter coupled wheels, 18in by 26in cylinders and a " B " class boiler with a working pressure of 160 lb per square inch, giving a tractive effort of 12,960 lb. A larger " H " class boiler with a working pressure of 175 lb per square inch was fitted in June, 1904, raising the tractive effort to 14,487 lb. In 1907 the ten engines were renumbered 378–387 and the entire class was later rebuilt by Henry Fowler. When No. 383 was dealt with in 1909 a " G.7 " boiler was fitted, but the working pressure and tractive effort remained the same. The total mileage run by No. 40383 was 1,604,149.

BRITISH RAILWAYS WIND TUNNEL.—British Railways are to build a new 100 m.p.h. wind tunnel testing plant at Derby to provide data for the design of locomotives, carriages, wagons and railway structures. It is stated that among the subjects to be studied will be improved train ventilation, dispersal of smoke and steam, wind resistance of wagons used in high-speed freight trains, design of draught-proof signal lamps, extraction of smoke from engine sheds, and cooling of diesel locomotives. The tunnel will be housed in a separate building close to the Railway Research Laboratory. It will be operated by an air screw driven by a 50 h.p. motor, which will draw air through at varying speeds up to 100 m.p.h. The tunnel will be of the return flow type, which enables use to be made of the unexpended velocity of the air as it returns. Tests will be carried out with models of such items as trains and buildings where full-scale experiments are impracticable. The new tunnel is expected to be in use by the end of this year.

Air and Water

PORT OF LONDON SHIPPING.—During the week ended August 30th, the number of vessels using the Port of London was 819, representing 983,708 net tons, which figure excluded certain vessels trading regularly with coastwise ports. Of these vessels, 376, aggregating 677,778 net tons, were to and from Empire and foreign ports.

ROYAL AERONAUTICAL SOCIETY.—The eighth British Commonwealth and Empire Lecture of the Royal Aeronautical Society will be delivered at a meeting to be held in the hall of the Institution of Mechanical Engineers, Storey's Gate, Westminster, S.W.1, on Thursday, October 2nd, at 6 p.m. The lecturer is Mr. R. E. Hardingham, secretary and chief executive of the Air Registration Board, his subject being " Maintaining Airworthiness in Operation."

THE LATE MR. H. S. HUMPHREYS.—We record with deep regret the death of Mr. Herbert Septimus Humphreys, M.I.Mar.E., M.I.N.A., of 25, The Avenue, Gravesend, which occurred in London on Friday last, September 5th. Mr. Humphreys, who was sixty-two, had been chief engineer superintendent of the British Tanker Company since 1942, having joined the company's engineering staff early in 1921. Prior to that he had served on the staff of Lloyd's Register of Shipping. During the war, Mr. Humphreys took a leading part in the work of preparing specifications for tankers suitable for wartime construction, and in recent years he had been responsible for the design and construction of a large number of new tankers for his company. Mr. Humphreys was a member of the Institution of Naval Architects, a gold medallist of the North-East Coast Institution of Engineers and Shipbuilders, and a Denny gold medallist of the Institute of Marine Engineers. He was also a member of the council of the Shipping Federation.

Miscellanea

ELECTION OF MASTER CUTLER.—At a ceremony in Sheffield on Tuesday last, Sir Harold West, managing director of Newton Chambers and Co., Ltd., was elected Master Cutler. He will be installed on October 7th.

I.E.E. PRESIDENTIAL ADDRESS.—The opening meeting of 1952–53 session of the Institution of Electrical Engineers will be held at Savoy Place, Victoria Embankment, London, W.C.2, on Thursday, October 9th, at 5.30 p.m., when Colonel B. H. Leeson will deliver his Presidential Address.

EXAMINATIONS IN FUEL TECHNOLOGY.—A new scheme for examinations in fuel technology has been devised by the Institute of Fuel in conjunction with the City and Guilds of London Institute. Particulars of it are now available and may be obtained from the Institute of Fuel, 18, Devonshire Street, London, W.1.

LECTURE COURSES ON TRAFFIC ENGINEERING.—In addition to the courses on road materials and construction which have already been announced, a course on road safety and traffic, of seven days' duration, is to be held at the Road Research Laboratory from February 24 to March 4, 1953, inclusive. The courses will include the most recent results of research and thought on factors relevant to road safety and traffic engineering. A fee of £7 7s. will be charged, and forms of application may be obtained from the Director, Road Research Laboratory, Harmondsworth, West Drayton, Middlesex.

THE LATE MR. S. D. ORR.—We have learned with regret of the death of Mr. S. D. Orr, which occurred, after a long illness, on August 29th. Mr. Orr was a technical representative of Sir W. G. Armstrong Whitworth and Co. (Ironfounders), Ltd., Gateshead-on-Tyne, with which firm he had been associated for over fifteen years.

NOTTINGHAM POWER STATION EXTENSION.—The British Electricity Authority has received the consent of the Minister of Fuel and Power to the extension of the Nottingham power station by the installation of a 60MW turbo-generator set and two boilers, each having an evaporative capacity of 300,000 lb of steam per hour. The present installed capacity of the station is 254MW.

SWEDEN'S IRON ORE PRODUCTION.—According to *The Anglo-Swedish Review*, iron ore production in Sweden last year amounted to 15,390,000 tons, valued at 433,000,000 kronor. This was an increase of nearly 2,000,000 tons compared with the preceding year. Last year's exports of iron ore from Sweden were valued at 15,000,000 kronor. The total amount of pig iron produced in Sweden last year was 851,300 tons.

INSTITUTION OF MECHANICAL ENGINEERS.—The annual dinner of the Institution of Mechanical Engineers will be held at the Dorchester Hotel, Park Lane, London, W.1, on Thursday, October 16th, at 7 for 7.30 p.m. On the following evening, Friday, October 17th, at 5.30 p.m., Sir David Pye, F.R.S., will deliver his presidential address, entitled " The Art of the Practical Engineer," at a general meeting of the Institution, to be held at Storey's Gate, Westminster, S.W.1.

ELECTRICAL ASSOCIATION FOR WOMEN.—The Electrical Association for Women is holding a one-day conference on " The Teaching of Electrical Housecraft " at the Yorkshire Training College of Housecraft, Leeds, on November 15th. The subjects to be considered include " The Use and Care of Electric Cookers, Cooking Equipment and Refrigerators," " The Use and Care of Electrical Laundry Equipment," and " The Teaching of Electrical Housecraft in Schools."

COLORADO SCHOOL OF MINES.—The Colorado School of Mines announces the appointment of Mr. Lute J. Parkinson as head of its mining department, in succession to Mr. Clifton W. Livingston. Mr. Parkinson has had extensive experience in mine examination work and production operations in Europe, Africa and North and South America, followed by a long period of administrative positions. In 1950, he was awarded the School of Mines' highest honour, when he was presented with " a distinguished achievement award."

" BUILDING TO-DAY " EXHIBITION.—A " Building To-Day " Exhibition, showing training and opportunities of advancement offered by the industry to young men on the threshold of a career, is to be held at the East Ham Technical College (Department of Building), Arragon Road, London, E.6, from October 14th to 18th inclusive. The exhibition has been organised by the County Borough of East Ham Education Committee in collaboration with the London Building and Civil Engineering Joint Committee, the London Master Builders' Association (North-East Area), and the National Federation of Building Trades Operatives (London Region Council), and is supported by the Ministry of Works. College classes and workshops will be open to visitors during the day and evening, and demonstrations of portable powered tools will be given in the carpentry and joinery shops. Films of technical interest will be shown daily. Competitions have been arranged for students and apprentices in bricklaying, plumbing, carpentry and joinery, plastering, painting and decoration, and in certain selected classroom subjects. These are to be held before the start of the exhibition, and the prizes will be presented on the opening day. In addition there will be an open essay competition for boys visiting the exhibition. The exhibition will be open daily from 11 a.m. to 9 p.m.

PORTUGUESE DEVELOPMENT PLAN.—The Portuguese Government has announced a development plan to be carried out during the next six years, both in continental Portugal and in the overseas territories, and providing for a total investment of 13,500 million escudos, of which 7500 million will be allocated to Portugal itself and 6000 million to the different colonies and overseas territorities in Africa, India and the Far East. The plan is to be submitted to the National Assembly for approval at the beginning of the next session, which starts in November. It is stated that as far as continental Portugal is concerned, the largest single group of investments is concerned with hydro-electric power schemes and power transmission and distribution. Four schemes are contemplated in the plan, two of which have already been started. The increase in power production is expected to amount to 1210 million kWh per year by 1958. A corresponding system of power transmission and distribution throughout the country will be built up. The total sum to be invested in these works will be 2430 million escudos. The industrialisation of the country has been one of the main objects of the Government for several years and important sums are to be devoted to industrial projects, some of which are already being carried out. Investments in industry contemplated in the plan are as follows :—Oil refining, 280 million escudos ; iron and steel industry, 250 million ; a tinplate factory, 120 million ; production of fertilisers, 105 million ; cellulose and paper industry, 65 million escudos.

THE G.E.C. HANDBOOK OF ELECTRICAL INSTALLATION MATERIAL.—The General Electric Company, Ltd., Magnet House, Kingsway, London, W.C.2, has published the *G.E.C. Handbook of Installation Material*, which covers that part of the company's products that is concerned with electrical installation work in factories and commercial and domestic buildings. This 800-page handbook is provided with a letter index, which gives a quick method of finding any of the twenty-four main sections, ranging from conduit and conduit fittings, wires cables and flexibles, to lighting fittings, fans, battery chargers, motors, and motor starters. There is an alphabetical index and a numerical index based on the G.E.C. catalogue sections and containing more than 4000 entries. The prices given in the handbook are those current in the first quarter of 1951. An overseas edition of the handbook will be available in November next.

SUGAR BEET HARVESTING MACHINERY.—The seventh annual demonstration of sugar beet harvesting machines, arranged by the British Sugar Corporation, Ltd., is to be held at Chrishall Grange, Heydon, on the Essex-Cambridgeshire border, on Thursday and Friday, October 23rd and 24th. It is expected that twenty-six different machines will be shown at work, including those by British makers and some of foreign origin. Among the latter are machines produced by Swedish, Danish, Irish and German engineers. Many of the machines, it is stated, incorporate beet top saving equipment, and for the first time at these demonstrations beet harvesters drawn by tractors travelling outside the crop will be on view. Another important process to be included in the demonstration is the drying of tops on the field, and there will also be shown in operation a Danish machine which has been designed to clean and lift the beet tops.

Personal and Business

MR. T. R. B. SANDERS has been appointed engineering adviser to the British Standards Institution, 24, Victoria Street, London, S.W.1.

MR. ROY C. ORFORD, M.Sc., A.M.I.E.E., has been appointed patents manager to Power Jets (Research and Development), Ltd.

PARKER, WINDER AND ACHURCH, Ltd., Birmingham, has opened new offices and showrooms in London at 16, Grosvenor Place, S.W.1 (telephone, Sloane 2339).

THE BRISTOL AEROPLANE COMPANY, Ltd., announces that Mr. C. B. Bailey-Watson, lately the Technical Editor of *Flight*, has been appointed public relations manager.

ROLLS-ROYCE, Limited, announces that Air Marshal Sir Colin W. Weedon, K.B.E., C.B., is joining its organisation. He will be concerned with the export side of the aero-engine division.

ROLLS-ROYCE, Ltd., Derby, states that Mr. J. D. Pearson, Wh.Sc., M.I.Mech.E., has been appointed chief executive of its aero division. Mr. H. F. Kelley, A.M.I.C.E., A.M.I.Mech.E., has been appointed general manager (manufacturing) for the division.

THE DAVID BROWN GROUP announces the formation of a new company entitled David Brown (Australasia) Proprietary, Ltd., with headquarters at 82, Pitt Street, Sydney. The company will be responsible—with Mr. P. J. Clifford as manager—for the import and distribution throughout Australasia of the products of David Brown Tractors (Engineering), Ltd., Meltham, Yorks.

THE MINISTRY OF SUPPLY announces that Mr. A. E. Woodward-Nutt, M.A., F.R.Ae.S., has been appointed principal director, research and development (aircraft). He will supervise and co-ordinate the work of the following four directorates: military aircraft research and development (R.A.F.), of which Air Commodore G. Silyn Roberts, C.B.E., F.R.Ae.S., has been appointed director ; military aircraft research and development (R.N.), of which Captain (E) C. W. Jones, M.I.Mech.E., R.N., has been appointed director ; civil aircraft research and development, with Mr. J. M. Gray as director ; and aircraft servicing research and development, in which Air Commodore W. A. Opie is to succeed Air Commodore G. B. M. Rhind as director.

Catalogues

HUGH WOOD AND CO., Ltd., Gateshead-on-Tyne.—Illustrated catalogue of Huwood-Hudswell diesel locomotives, Mines Type 68 and 100 h.p.

CHASESIDE ENGINEERING COMPANY, Ltd., Station Works, Hertford, Herts.—Leaflet dealing with the improved version of the Chaseside Shovel.

WILD-BARFIELD ELECTRIC FURNACES, Ltd., Elecfurn Works, Watford By-Pass, Watford, Herts.—Catalogue dealing with Horizontal Hairpin Furnaces.

NEWTON LANSDOWNE AND CO., Ltd., Brook House, 2, Torrington Place, London, W.C.1.—Catalogue describing " Elmeg " electromagnetic presses.

GENERAL ELECTRIC COMPANY, Ltd., Magnet House, Kingsway, London, W.C.2.—Catalogue No. 1492, dealing with flameproof and safety equipment.

RAPID MAGNETIC MACHINES, Ltd., Lombard Street, Birmingham, 12.—Publication No. 122, dealing with electro-magnetic chute type separators. Publication No. 134, giving details of range of permanent magnetic equipment.

British Patent Specifications

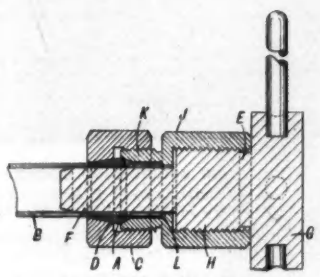
When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification.

Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 2s. 8d. each.

TUBE AND PIPE COUPLINGS

677,250. July 8, 1949.—JOINTS OR COUPLINGS FOR PIPES, The Railway Appliances Company, Ltd., Elm Road, Hook, Surbiton, Surrey, and Arthur Prosper Cullen, of the company's address.

The object of the invention is to provide a simple and efficient method of and means for applying joint making rings to pipes, such as soft or relatively soft copper or other metal or alloy pipes, without collapsing or distorting the walls of the pipes, so enabling compression couplings to be used. Referring to the drawing, *A* is an externally coned joint making ring and *B* a portion of pipe to which it is to be applied, *C* being the union or compression nut, which has a coned internal surface *D* engaging the coned surface of the ring. The pipe is relatively soft and the ring has annular serrations on its internal surface, which are pressed into the pipe wall and ensure a fluid-tight joint and the maintenance of the

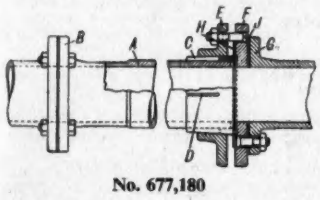


No. 677,250

ring in its correct position on the pipe. To enable the ring to be applied to the relatively soft pipe without collapsing or distorting it, it is necessary to support the tube wall internally while stressing the ring. The apparatus shown in the drawing comprises a pipe wall supporting member or plug *E*, having one end *F* of reduced diameter and forming a mandrel for insertion into the end of the pipe *B*. The mandrel is long enough to extend through the location of the joint ring and it fits closely the bore of the pipe. At its other end the plug has a head *G* by means of which it may be rotated or held against rotation as required. The body portion *H* between the head and mandrel of the plug is threaded to receive a holding or abutment sleeve *J*, which has a reduced diameter end portion *K* that encloses the end portion of the pipe and an internal shoulder *L* against which the end surface of the pipe abuts. The sleeve is made hexagonal for turning by means of a spanner and the head *G* is provided with holes to receive the end of a tommy bar by which the plug may be turned or held.—*August* 13, 1952.

677,180. March 22, 1950.—A MAKE-UP PIPE CONNECTION, Miag Vertriebsgellschaft m.b.H., Braunschweig, Germany.

In the usual construction a pipe *A* has at one of its ends a fixed flange *B*, and the other end can be somewhat thickened to permit machining. In accordance with the invention a bush *C* having formed in it slits *D* is fitted to slide on this machined pipe end. This allows the length of the pipe *A* to be extended or shortened by sliding the bush and fitted over it is a corresponding flanged member along it. The external surface of the bush is tapered,



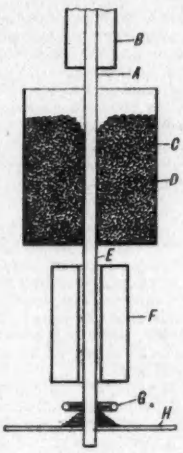
No. 677,180

E. The flanged bush member is connected by means of screws with a loose ring member *F*, which in turn can be attached to the flange of an adjacent pipe *G*. Between the adjacent edges of the bush *C* and the loose ring member *F* and the pipe flange *G* packings *H* and *J* are provided. The pipe *A* can be considered as the last intermediate or "make-up" piece of a substantially completed pipe-line assembly, so cut that it will fit between two pipes already installed. Dismantling the pipe connection presents no difficulties.—*August* 13, 1952.

METALLURGY

677,419. February 6, 1951.—COOLING ENDLESS CASTINGS, Mannesmannrohren-Werke, Dusseldorf, Germany, Huttenwerk Huckingen A.G., Duisburg-Huckingen, Germany, and Westdeutsche Mannesmannrohren Aktiengesellschaft, Dusseldorf, Germany.

The invention relates to a method of cooling the endless casting which is formed in the continuous casting of steel, iron and other metals. As shown in the drawing, the endless casting *A* leaves the lower part *B* of the continuous casting mould. The casting passes through a container *C* having appropriate apertures, in which a mass of granulated blast furnace slag *D* is contained. At the commencement of the continuous casting a plug in the centre of the container *C* is forced downwards through the slag by the casting. As soon as the casting comes into contact with the slag, it melts the grains in the neighbourhood of the metal, and they form a thin layer *E* on the surface of the casting. The heat consumed in the melting is derived from the casting, which is thereby cooled, for example, from 1400 deg. to 1300 deg. Cent. About 50kg to 60kg of blast furnace slag to 1 ton of steel is required to effect such cooling, in the case of an endless steel casting. Due to the reducing action of the blast furnace slag, undesirable oxidation of the casting is prevented. Following the cooling of the casting by a melting material, a further cooling can take place by radiation, the casting being passed through a water-cooled duct *F*. The thin layer of slag *E* can be removed from the casting by spraying with water by an annular nozzle *G*, which causes the layer of slag to crack off. The slag collects on a plate *H* having an aperture for the passage of the casting.—*August* 13, 1952.

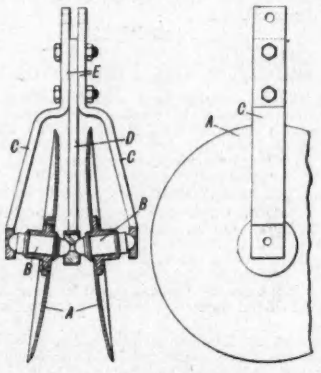


No. 677,419

AGRICULTURAL ENGINEERING

677,254. August 17, 1949.—DISC CULTIVATORS, Heinrich Reining and Co., G.m.b.H., Hansa-Allee 305, Dusseldorf-Oberkassel, Germany.

This invention relates to disc cultivators and the easy adjustment of the discs. Referring to the drawing, the dished discs *A* are journalled on shafts *B*. Each shaft is symmetrically mounted with respect to



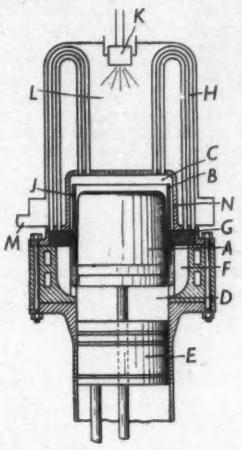
No. 677,254

the other in the outer prong *C* and the central prong *D* of a fork. The ends of the shafts are hemispherical and engage in bearings in the form of cups which are shaped correspondingly to the ends of the shafts. The middle prong *D* is adjustable as to height and, for this purpose, it is provided with elongated slots through which pass bolts by which it is connected to the shanks *E* of the outer prongs.—*August* 13, 1952.

AIR ENGINES

677,297. May 11, 1950.—HOT-GAS RECIPROCATING ENGINES, N. V. Philips' Gloeilampenfabrieken, Emmasingel 29, Eindhoven, Holland.

The invention provides a hot-gas reciprocating engine comprising a heater which at least partly surrounds the hot space, the outer surface of the wall of the hot space being exposed to the action of the combustion gases of the heater, wherein the wall or a part of it can be cooled by a supply of working medium flowing through a channel separated from passages in the heater. Referring to the drawing, a displacer-piston *A* reciprocates in a bushing *B*. The space above the displacer is the hot space *C*. Most of the working medium flows between the cold space *D*, the volume of which is determined by a piston *E*, and the displacer *A* and the hot space *C*. through a cooler *F*, a regenerator *G* and a heater *H*.



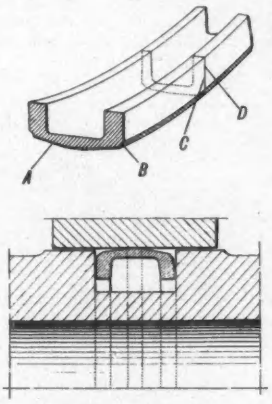
No. 677,297

A relatively small amount of the working medium flows through the annular channel *J* directly between the regenerator and the hot space. Above the engine head a burner *K* is provided, the combustion gases of which flow between the groups of pipes of the heater. This heater is formed by two concentric groups of "U"-shaped pipes arranged to surround the combustion space *L* and constituting passages for the working medium. The combustion gases, after passing between the pipes, leave the heater at *M*, and also flow around the top and side wall of the engine head *N*. A risk of excessive heating of the engine head is thus incurred. However, since part of the working medium flows through the annular channel *J* to the hot space *C* this risk is mitigated. The relatively smaller amount of working medium flowing directly between the hot space *C* and the regenerator *G* necessary for cooling purposes, varies somewhat with the temperature of the hot and cold spaces. The invention provides cooling of the wall of the hot space and may be used with other heater constructions.—*August* 13, 1952.

INTERNAL COMBUSTION ENGINES

677,663. April 18, 1950.—SEALING RINGS FOR INTERNAL COMBUSTION ENGINE CYLINDER LINERS, l'Auxiliaire Industrielle, 17, rue Marbeuf, Paris, France.

The upper view shows a section of a sealing ring taken near the point where both ends of the ring are abutting against each other. The ring, which is made of steel, has the shape of a "U" in radial cross-



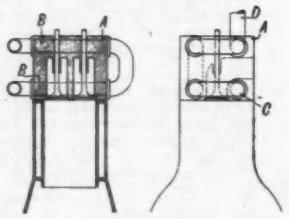
No. 677,663

section, both legs of the "U" projecting towards the centre line of the ring; the outer periphery *A* of the ring is slightly convex, as shown, and is bevelled at *B* on either side; the ends *C* and *D* of the ring abut against each other. In the abutment plane the outer faces of the legs are made clean without any

burr ; also the outer edges along the free ends of the legs are kept sharp and clean, in order that water-tightness of the joint is secured. In the lower view the ring is shown as mounted in place between the cylinder liner and the cylinder housing. It is inserted in an annular groove having extending lateral sides cut in the outer surface of the liner, the groove being given a width slightly greater than that of the ring. The ring is inserted into the groove and its convex periphery projects from the groove beyond the outer periphery of the liner. Then the liner is forced within the bore of the housing, which is slightly less than the maximum outer diameter of the ring when the ends abut against one another, so that the ring is applied tightly against the wall of the housing bore. Due to the convexity of the outer periphery of the ring, the pressure exerted on it by the cylinder housing causes the legs of the seal-ring to be displaced away from each other and the outer edges of the free ends of the legs to be applied tightly against the lateral sides of the annular groove.—*August* 20, 1952.

677,462. December 30, 1949.—COOLING OR HEATING OF ENGINE PARTS, Sudwerke G.m.b.H., Kronacherstrasse Kulmbach/Oberfranken, Germany.

This invention relates to cylinder heads of internal combustion engines, having a channel for the passage of cooling or heating medium and provides a construction convenient to manufacture. Referring to the drawings, the cylinder head *A* is provided with a channel *B* consisting of simple, straight sections, each of which enters and emerges from the cylinder



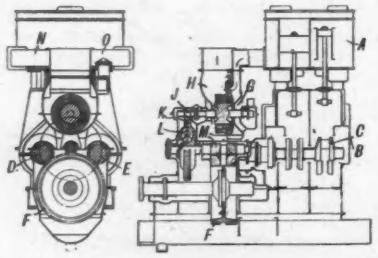
No. 677,462

head separately. These parts of the channel are interconnected outside the cylinder head in such a way that the cooling medium, in this example water, entering through the connecting pipe *C* flows through them in succession, after which it is discharged through the pipe connection *D*. Overhead valves are shown but it will be understood that the invention can equally well be applied to a side valve engine. The invention can also be employed in air cooling of internal combustion engines.—*August* 13, 1952.

MARINE ENGINEERING

677,153. December 6, 1949.—COMBINATION OF A PISTON STEAM ENGINE AND AN EXHAUST STEAM TURBINE, Aktiengesellschaft "Weser," Werftstrasse, 18, Bremen, 13, Germany.

As the drawing shows, the high-speed piston steam engine *A* has the two crankshafts *B* and *C*, which drive through the pinions *D* and *E*, the main gearwheel *F* of the propeller shaft. In the vertical plane of the gearwheel there is located the axial midpoint of the turbine rotor *G* of the low-pressure turbine *H*, which is arranged above the gearing. Behind the main gearwheel is an intermediate gear



No. 677,153

train *J* and *K*, the main gearwheel *K* of which is connected to the fluid coupling *L*. The driven part of the fluid coupling drives a pinion *M*, which meshes with the main gearwheel of the engine gearing. Between the gearcase and the turbine a sufficient ventilation space is provided. The exhaust steam is conveyed through pipes *N* and *O* from the low-pressure cylinders of the steam engine to the turbine. The whole structure is mounted on a common base-plate.—*August* 13, 1952.

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 24, Victoria Street, London, S.W.1.

SOLID-DRAWN ALUMINIUM BRONZE TUBES FOR GENERAL PURPOSES (7 PER CENT ALUMINIUM)

No. 1867 : 1952. The standard gives the chemical composition and mechanical properties and includes details of making the mechanical tests and a mercurous nitrate test. Tolerances on width, length and thickness are tabulated. Price 2s. 6d.

VULCANISED RUBBER COMPOUNDS

No. 1154 : 1952. This standard replaces the war emergency specification published in 1944, which was based on the earlier Government Department Specification T.G.25A. The new standard covers four white compounds and six black compounds, the former being produced from natural rubber and zinc oxide, and the latter from natural rubber, zinc oxide and lamp black. The various compounds are classified according to their hardness.

The standard includes skeleton compositions as well as testing requirements and an appendix includes mixes which give vulcanizates complying with the requirements of the standard. Price 2s. 6d.

FLANGED STEEL GLOBE VALVES FOR THE PETROLEUM INDUSTRY

No. 1873 : 1952. This is another standard in the series that is being prepared for the petroleum industry. It covers cast or forged steel outside-screw-and-yoke globe valves with integral flanges and ball or plug type discs, the seat rings being renewable and either shoulder-seated or bottom-seated. The permissible pressure is a maximum of 1000 lb per square inch for valves of class 300 and above for valves ¾–8in size.

The standard includes provisions relating to design and manufacture, materials, workmanship, marking, tests, inspection, dispatch and guarantee. A number of appendices and two detailed drawings illustrating the valves covered and providing identification of the various parts of the valves are included in the specification. Price 10s.

SYNTHETIC-RESIN BONDED PAPER INSULATING TUBES

No. 1885 : 1952. This standard sets out the minimum requirements for synthetic-resin bonded paper rectangular tubes for use on electrical power circuits up to 1000V. It is an addition to the published series dealing with insulating material and, apart from the voltage limitation, is complementary to B.S. 1314 (1946), which covered circular tubes of similar material. The new specification deals with two types of rectangular tube intended for electrical insulating purposes with direct-current and with alternating-current up to 100 c/s. The internal side dimensions of the tubes specified range from ¼in up to 6in with wall thicknesses of from $\frac{1}{32}$in to ½in. Electrical and mechanical properties are specified, together with the tolerances on dimensions. Methods of test, including the preparation and conditioning of specimens prior to test, are fully described in appendices. Price 2s. 6d.

Launches and Trial Trips

BINNA, cargo vessel ; built by Hall Russell and Co., Ltd., Aberdeen ; length between perpendiculars 265ft, breadth moulded 44ft, depth moulded to main deck 19ft 3in, draught 16ft 10in, deadweight 2500 tons ; double compounded, four-cylinder Hall-Russell-Fredriksstad engine ; two single-ended oil-fired boilers, 220 lb per square inch, 600 deg. Fah. Launch, September.

HOEGH RIDER, single-screw oil tanker ; built by Joseph L. Thompson and Sons, Ltd., Sunderland, for Lief Hoegh and Co., of Oslo ; length between perpendiculars 475ft, breadth moulded 67ft 4in, depth moulded 37ft 4in ; deadweight 15,135 tons ; speed 12½ knots ; Doxford four-cylinder opposed-piston engine, 670mm diameter, 2320mm combined stroke. Launch, September 3rd.

TYNEFIELD, single-screw motor tanker ; built by R. and W. Hawthorn, Leslie and Co., Ltd., Hebburn for Hunting and Son, Ltd.; length overall 557ft, breadth moulded 70ft, depth moulded to upper deck 39ft 6in ; deadweight 18,500 tons ; Hawthorn-Doxford engine, six cylinders, 725mm bore by 2250mm stroke, 7600 b.h.p. at 114 r.p.m. Trials, September 2nd and 3rd.

ROMANDIE, single-screw motor cargo vessel ; built by the Burntisland Shipbuilding Company, Ltd., for Suisse Atlantique Societe de Navigation Maritime S.A., of Lausanne, Switzerland ; length between perpendiculars 430ft, breadth moulded 59ft 9in, depth moulded to shelter deck 39ft 3in ; deadweight 10,825 tons ; Sulzer two-stroke engine, six cylinders, 720mm bore by 1250mm stroke, 3940 h.p. at 121 r.p.m. Trial, September 3rd.

RAMSAY, single-screw steam cargo vessel ; built by Smith's Dock Company, Ltd., South Bank-on-Tees, for the Bolton Steam Shipping Company, Ltd.; length overall 450ft 8in, breadth moulded 59ft, depth moulded to upper deck 38ft 3in ; deadweight 9950 tons ; speed 11½ knots ; triple-expansion engine, developing 3000 equivalent i.h.p. when working in conjunction with Bauer-Wach exhaust turbine. Launch, September.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office on, or before, the morning of the Monday of the week preceding the meetings. In all cases the TIME and PLACE *at which the meeting is to be held should be clearly stated.*

ASSOCIATION OF SPECIAL LIBRARIES AND INFORMATION BUREAUX

Fri. to Mon., Sept. 19th to 22nd.—The Hayes, Swanwick, Derbyshire, Conference on "Information Service : Theory and Practice."

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

Mon., Sept. 15th.—N.W. LONDON BRANCH : Prince of Wales Hotel, Kingsbury, "Electronically Controlled Driving Equipment," F. Ralph, 7.30 p.m.

Wed., Sept. 17th.—COVENTRY BRANCH : Technical College, Coventry, "Ductube," 7.15 p.m.——MANCHESTER BRANCH : Engineers' Club, Albert Square, Manchester, "Wire Ropes," Film, 7.30 p.m.——S.W. LONDON BRANCH : Guild House, 32, Worple Road, Wimbledon, "M.I.C.C. Lighting, Power, Heating and Thermocouple Cables," G. E. D. Redman, 8.15 p.m.

BRITISH INSTITUTION OF RADIO ENGINEERS

Tues., Sept. 23rd.—W. MIDLANDS SECTION : Technical College, Wulfruna Street, Wolverhampton, "A Pulse Tester for Coaxial Cables," N. S. Dean and E. Carey, 7.15 p.m.

Thurs., Oct. 2nd.—SCOTTISH SECTION : Department of Natural Philosophy, The University, Edinburgh, "Recent Developments in Television," H. McGhee, 7 p.m.

CHEMICAL SOCIETY

Wed., Oct. 1st.—BRISTOL SECTION : Premier Hall, Stroud, "Synthetic Fibres," B. T. Ridge, 7.15 p.m.

Thurs., Oct. 2nd.—BRISTOL SECTION : Chemistry Department, The University, Bristol, "Some Metallurgical Problems Imposed by Stratosphere Flight," P. L. Teed, 7 p.m.

ENGINEERS' GUILD

Thurs., Sept. 25th.—METROPOLITAN BRANCH : Caxton Hall, Caxton Street, Westminster, S.W.1. Annual General Meeting, 6 p.m.

ILLUMINATING ENGINEERING SOCIETY

Mon., Sept. 29th.—LEICESTER CENTRE : E. Midlands Electricity Board, Charles Street, Leicester, "Horticultural Lighting," J. J. French, 6.30 p.m.

Tues., Sept. 30th.—CARDIFF CENTRE : S. Wales Electricity Board, Cardiff, Chairman's Address, A. J. Dalton, 5.45 p.m.

INCORPORATED PLANT ENGINEERS

Sat., Sept. 13th.—DUNDEE BRANCH : Works visit to Expanded Rubber Company, 2.15 p.m.

Mon., Sept. 15th.—LIVERPOOL AND N. WALES BRANCH : Radiant House, Bold Street, Liverpool. "Amenities in Industry," H. S. Crump, 7.15 p.m.

Tues., Sept. 16th.—ST. ALBAN'S BRANCH : Peahen Hotel, St. Albans, "Radio and Television Interference," C. E. Hollingworth, 7.30 p.m.——GLASGOW BRANCH : Engineering Centre, 351, Sauchiehall Street, Glasgow, "Mechanical Handling Equipment and Methods," F. T. Dean, 7 p.m.

Thurs., Sept. 25th.—S. YORKSHIRE BRANCH : Grand Hotel, Sheffield, "Hazards and Regulations in Steelworks," 7.30 p.m.

Fri., Sept. 26th.—BIRMINGHAM BRANCH : Imperial Hotel, Temple Street, Birmingham, "Modern Factory Lighting," F. Jamieson, 7.30 p.m.

INDUSTRIAL WELFARE SOCIETY

To-day to Sat., Sept. 13th.—Keble College, Oxford, Third Annual Conference for Apprentices, Theme : "The Approach to Industrial Responsibility."

INSTITUTE OF FUEL

Tues. and Wed., Oct. 28th and 29th.—Institution of Mechanical Engineers, Storey's Gate, St. James's Park, London, S.W.1, Conference, "A Special Study of Ash and Clinker in Industry."

INSTITUTE OF ROAD TRANSPORT ENGINEERS

Wed., Oct. 1st.—Royal Society of Arts, John Adam Street, London, W.C.2, Annual General Meeting, 6.30 p.m.

INSTITUTION OF CHEMICAL ENGINEERS

Thurs., Sept. 18th.—N.W. CENTRE, GRADUATES' AND STUDENTS' SECTION : Visit to the works of Petrochemicals, Ltd., Partington, 2.30 p.m. (details from B. Pollard, Monsanto Chemicals, Ltd., Ruabon, Denbighshire).

INSTITUTION OF LOCOMOTIVE ENGINEERS

Wed., Sept. 24th.—Institution of Mechanical Engineers, Storey's Gate, St. James's Park, London, S.W.1, Presidential Address, C. M. Cock, 5.30 p.m.

INSTITUTION OF MINING AND METALLURGY

Tues. to Thurs., Sept. 23rd to 25th.—Imperial College of Science and Technology, Prince Consort Road, South Kensington, London, S.W.7, Symposium on Mineral Dressing.

INSTITUTION OF PRODUCTION ENGINEERS

Wed., Sept. 17th.—BIRMINGHAM SECTION : James Watt Memorial Institute, Great Charles Street, Birmingham, Discussion on "Examples of Economy in Material Usage," 7 p.m.——EDINBURGH SECTION : North British Station Hotel, Princes Street, Edinburgh, "The Social Functions of Industry," A. Roberts, 7.30 p.m.

INTERNATIONAL MACHINE TOOL EXHIBITION

Wed. to Sat., Sept. 17th to Oct. 4th.—Olympia, London.

IRON AND STEEL INSTITUTE

Tues. to Thurs., Oct. 7th to 9th.—Special meeting in Swansea.

NEWCOMEN SOCIETY

Wed., Sept. 17th.—Science Museum, South Kensington, London, S.W.7, Special General Meeting, "History and Particulars of the Brass Battery Process," B. de Soyres ; "Memorials to Engineers and Men of Science," E. C. Smith, 5.30 p.m.

OLD CENTRALIANS

Mon., Sept. 15th.—Chez Auguste Restaurant, 47, Frith Street, London, W.1, "The Muniments of Westminster Abbey," R. P. Howgrave-Graham, 12.55 p.m.